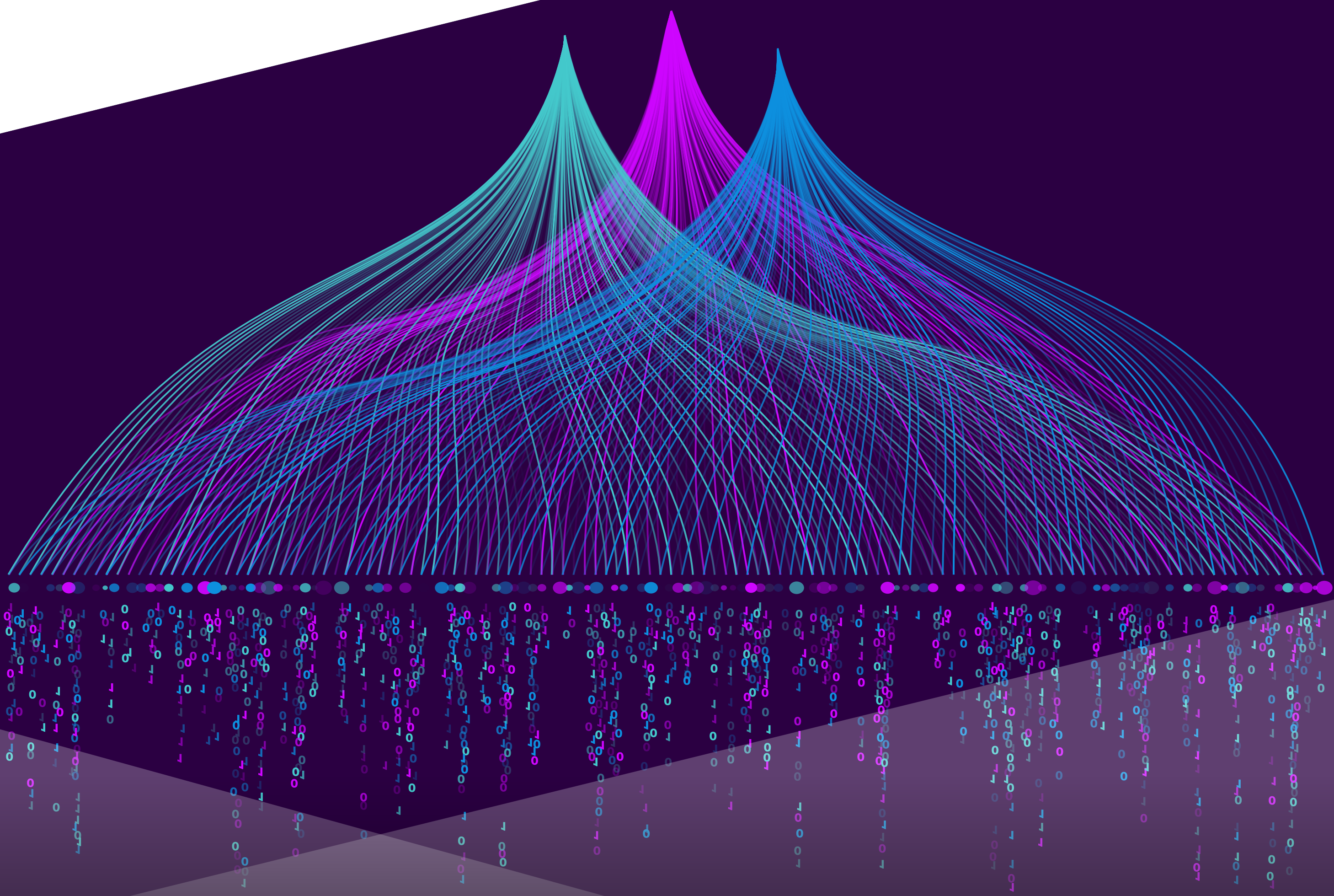
MARSH JLT SPECIALTY

INSIGHTS | MARCH 2020 | 26TH EDITION

100 Largest Losses in the Hydrocarbon Industry

1974-2019



MARSH

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100 Largest Losses in the Hydrocarbon Industry, 1974-2019

CONTENTS

Foreword

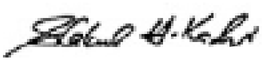
It is my pleasure and privilege to write this foreword for the 26th edition of Marsh JLT Specialty's *100 Largest Losses in the Hydrocarbon Industry* report.

I have found this publication to be very useful for leaders in the process industries to help them comprehend past incidents and lessons learned, as well as assist in the development of their improvement plans. At the Center for Chemical Process Safety (CCPS®), whose mission is to help prevent/minimize significant process safety incidents, we also take great interest in lessons and root causes identified in this document. CCPS was founded in 1985 in response to the Bhopal gas tragedy in Bhopal, India — its vision to protect people, property, and the environment through the collective wisdom of its corporate members and their stakeholders.

The recent period (2018-2019) covered in this document provides valuable information to start a dialogue on "Does Age Really Matter?" in our process safety improvement journey. Three of the new additions to the 100 largest losses occurred at oil refineries that were constructed more than 50 years ago. The largest loss in 2019 occurred at a refinery that was triggered by a failure of a thinned pipe elbow installed almost 50 years earlier. The component met the metallurgy requirement that was permitted at the time of installation; however, the component did not meet the intent of the American Society for Testing and Materials recommendations made 20 years later. With plants older than 30 years, the industry needs to look more closely at the risks associated with implementation of an effective asset/mechanical integrity programs; keeping facilities fit-for-service to meet the intent of newer critical safety standards, and keeping effective knowledge transfer. The best-in-class companies apply a formal engineering standards retrofitting program to ensure fitness to service requirement.

The exodus of an aging workforce has created a huge issue around how industry will meet its critical need of process safety knowledge transfer. This issue needs a holistic improvement approach, including enhanced education of process safety in engineering education, effective assimilation of process safety knowledge for early career industry professionals, and ongoing reinforcement of process safety training in the workforce. In recent years, many organizations have accelerated their effort to improve this area and progress is being made. My organization — AIChE/CCPS — in collaboration with its stakeholders, has put a great deal of effort into helping improve this critical need. This is a long-term issue that will require a collective effort by all stakeholders to progress effectively.

This report provides an excellent opportunity to look back at our history, at key issues these incidents have identified, and see if we are making progress. I urge all of you to review this document, and hope you will be able to extract learnings that you can apply to your organization to improve your process safety performance.



Shakeel H Kadri

SHAKEEL H KADRI

Executive director and CEO,
Center for Chemical Process Safety

American Institute of Chemical Engineers (AIChE)

The last two years have been turbulent; eight property damage losses from 2018-19 were among the 50-largest energy losses of all time.

Introduction

Welcome to the 26th edition of Marsh JLT Specialty's *100 Largest Losses in the Hydrocarbon Industry* report. The publication summarizes the 100 largest property damage losses from the hydrocarbon extraction, transport, and processing industry between 1974 and 2019.

It allows us to look back at our industry's history, identify key issues and trends from large losses, and understand whether the industry is making progress.

The report considers lessons that can be learnt from the past two years (page 05), and whether history is repeating itself 30 years on (page 13). The correlation between a plant's age and its impact on losses is then explored (page 19), before looking at how organizational resilience can help turn uncertainty into opportunity (page 25).

The report's information comes from Marsh JLT Specialty's energy-loss database, which includes information gathered from our deep involvement in the hydrocarbon industry, and also from public records. The information covers more than 40 years, and includes almost 10,000 individual loss records (see "Methodology" for more information). Graphics drawing on this database can be found on pages 29-33 and through the report.

The last two years have been turbulent; eight property damage losses from 2018-19 were among the 50-largest energy losses of all time. Four recent losses were among the 20-largest losses ever.

Not since 1988-89 (when six of the largest ever energy losses occurred — including Piper Alpha), has a two-year period seen such a high concentration of large losses.

Declining risk standards in some areas over the past 12 years may be a factor. For example, our risk engineer surveys found that "engineering standards" at refineries declined over this period, and that both gas processing plants and terminals/distribution underwent an overall deterioration in risk quality over the past 12 years.

We also found that plants older than 30 years are far more likely to experience losses, suggesting the industry needs to look more closely at the risks of older refineries and petrochemical plants.

The cause of loss tends to vary depending on the age of a plant, found Liberty Specialty Markets, a contributor to this report. In the first 10 years of a plant's operation, most losses are caused by operations-related failures.

As plant operations experience develops, the number of losses reduces, until age takes its toll and there is a steep rise in both loss frequency and magnitude in plants more than 30-years-old. In plants older than 30 years, mechanical-integrity-related failures account for 65% of losses.

Past Mistakes

The most commonly cited energy industry risk recommendations made by Marsh JLT Specialty over the past few years ("systems of work," "inspection," and "fireproofing") were prevalent issues among the largest issues in 1988-99 — reinforcing the view that the industry may not have learnt from past mistakes.

During the Piper Alpha incident in 1988, the largest industry property damage loss of all time, there were shortcomings in all three areas of the root cause "systems of work" (which includes permitting, management of change, and shift handover).

Similarly, the largest losses in 1988-1989 and 2018-19 both suffered from the escalating factors "emergency response plans" (ERPs) and "fire protection." For example, the lack of adequate ERPs caused the initial incident to escalate at Piper Alpha; at Campos Basin it took over a month to control the resulting fire, compounding the cost of the incident.

In 2018-19, in all four of the largest losses, the sites were not well prepared for the incidents that occurred. And in 2019 the US$600 million explosion at Limbe, Cameroon, began as a fire near a distillation unit on the refinery, which escalated to a much larger explosion. More robust fixed-fire protection at site may have reduced or prevented this escalation.

Four key factors arguably prevent lessons from being learnt from losses:

Distance
Parties unconsciously feel less affected by events a long way away.

Culture
Preventing lessons from being implemented effectively.

Tunnel vision
Not realizing wider relevance of lessons.

Time
Lessons are learnt, but then forgotten or solutions are insufficiently robust.

Given the 30 years that have elapsed between the two-worst periods in terms of the 20-largest losses, time would seem to be a particularly significant factor.

We hope this publication reminds energy-industry professionals of the range of losses that can occur, the range of potential root causes, the fallibility of prevention measures, and the scale of potential consequences. Only by reminding ourselves of these things, can we begin to make the progress and improvements that the whole industry wants to see.

Methodology

Although every effort has been made to find out as much information as possible about each of the losses referenced in this report, there are some losses for which we still have too little information, preventing us from determining the contributing factors. We have not included losses that occurred during projects' construction phase, and marine transportation losses are excluded except those involving marine vessels moored at plant docks.

The loss values are reported in two ways:

1. Adjusted property damage loss, based on the value of loss at the end of 2019.
2. Actual property damage loss, based on the value of the loss when it occurred.

Losses have been ordered according to the adjusted property damage loss values.

Loss amounts include property damage, debris removal, and clean-up costs. The costs of business interruption, extra expense, employee injuries/fatalities, and liability claims are excluded from this analysis. The direct on-premises clean-up costs due to asbestos abatement, polychlorinated biphenyl removal, or released hydrocarbons and chemicals following a fire, explosion, or other loss event have traditionally been considered part of the property damage loss.

CHAPTER 1

What Can We Learn From the Last Two Years?

Four of the new losses were among the 20-largest losses ever.

What Can We Learn From the Last Two Years?

Following a loss of more than US$1,000 million in 2017 — which ranks as one of the largest downstream property damage losses of all time — the past two years has been another turbulent period for the energy industry, with an unusually high number of large losses.

Of these new losses, a remarkable eight were among the 50-largest industry losses of all time, and four of these were among the 20-largest losses ever. Several more occurred that were just below the 100-largest losses threshold (which now stands at US$175 million).

New additions to the 100-largest losses (100LL) from the past two years cost an unusually large total of US$4.5 billion in property damage, which takes the total of the 100LL to US$43.2 billion (based on December 31, 2019, pricing).

The past two years have seen several major losses from refineries and petrochemical assets, particularly those built in the 1960s or earlier. Although not as prevalent in the 100LL, terminals/distribution and gas processing plants have also experienced large losses.

In this publication the large property damage losses have been grouped by type of facility into five categories of similar technology, to facilitate data comparisons:

FIGURE 1

Refineries accounts for half of all new additions to the 100LL.

SOURCE: MARSH

REFINERIES
Accounts for 50% of new additions and 39% overall.

TERMINAL & DISTRIBUTION
Accounts for 0% of new additions and 5% overall.

PETROCHEMICALS
Accounts for 25% of new additions and 26% overall.

UPSTREAM
Accounts for 0% of new additions and 24% overall.

GAS PROCESSING
Accounts for 25% of new additions and 6% overall.

Refineries

Four of the new additions to the 100LL occurred at oil refineries, and three of these occurred at sites more than 50 years old (the link between age of asset and large losses is explored more closely in "Does Age Really Matter?" on page 17).

The two largest refinery losses both happened in the US (Philadelphia US$750 million, and Wisconsin US$650 million), where there has been a well-publicized regulatory shift over the past two years including the rescinding of most of the Chemical Disaster Rule. This shift could be construed as representing a lighter regulatory touch from the Environmental Protection Agency, which has removed the following safeguards:

- The requirement that chemical companies must determine the root causes of spills or explosions.
- The requirement that an independent third party investigates spills, explosions, and other disasters.
- Training requirements for supervisors of plant operations.
- The requirement for the plant owner or operators to keep safety information up to date.
- The requirement that plant owners release chemical hazard information to the public upon request.

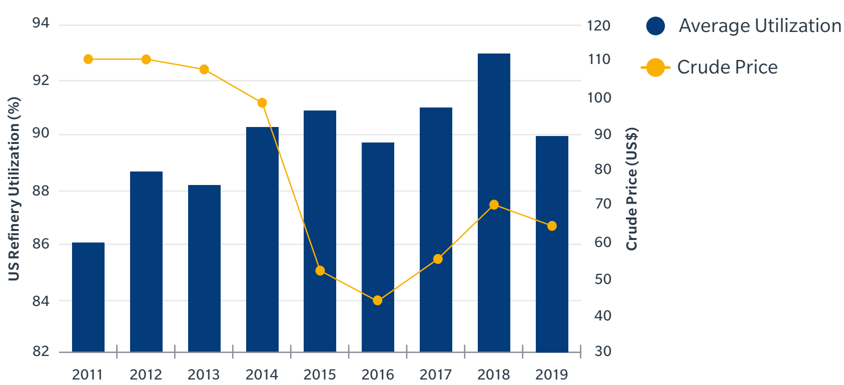
The largest new refinery loss occurred at Philadelphia and was triggered by a thinned pipe elbow installed almost 50 years earlier; it has been reported that this was found to contain a metallurgy permitted when it was originally installed, but not under recommendations made 20 years later by the American Society for Testing and Materials. Similar losses could occur in future if aging assets are not supported by evolving engineering standards that are enforced by adequate regulation.

Downstream margins are positively affected by drops in oil prices and this can result in refineries being pushed to operate at greater capacity (see figure 2), potentially contributing to the frequency of large losses. At the end of 2017, US refinery utilization stood at its highest level since 2005. This high utilization has continued over the past two years and may have contributed to the high number of recent losses.

FIGURE 2

Average US refinery utilization remained elevated in recent years while the price of crude oil remained relatively low.

SOURCE: MACRO TRENDS* AND US ENERGY INFORMATION ADMINISTRATION**



*www.macrotrends.net **https://www.eia.gov

High oil refinery utilization has continued over the past two years and may have contributed to the high number of recent losses.

US$
750M

The size of the largest refinery loss during 2018-19, occurring in Philadelphia and triggered by a thinned pipe elbow installed almost 50 years earlier.

A US$800 million loss in Jiangsu, China, was the largest petrochemical property damage loss since Pasadena 1989.

Petrochemical Plants

There have been a number of high-profile losses in the petrochemical sector in the past two years. Several of these occurred in the US, including the US$500 million loss in Houston (November 2019), and the US$100 million loss in Crosby (April 2019), which, like the Philadelphia refinery loss, was initiated by the failure of a piping component.

There was also an US$800 million loss resulting from an explosion in Jiangsu, China, which is the largest petrochemical property damage loss since Pasadena 1989. Following this, there has been a reported drive in China to increase regulation in order to raise minimum standards at petrochemical sites. This includes:

- A stipulation that local governments eliminate all hazards around production, storage, transportation, and waste disposal.
- Tighter zoning regulations that prevent chemical plants from being built near residential areas.
- New rules on the transportation and disposal of hazardous materials.

The recent large losses in both petrochemical and refining underline the challenges governments, globally, face when trying to strike the right level of regulation within an industry: Regulation will often need to allow for the fact that retrofitting facilities may sometimes be prohibitive in terms of cost, or impractical due to lack of available space.

What Does Risk Ranking Data Show?

To help companies understand and improve their risk profiles and reduce the occurrence and magnitude of losses, Marsh's risk engineers survey key energy assets. As part of these surveys, Marsh ranks the quality of hardware, software (management systems), and emergency response areas at sites, each of which are made up of a number of sub-topics.

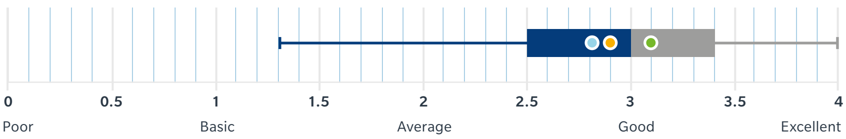
A look back over the past 12 years of ranking data shows that certain aspects examined in these surveys have deteriorated, which may have contributed to the trend of recent losses.

Of note is the scores given for "engineering standards" at refineries, which have declined over this period.

FIGURE 3

Average engineering standards at refineries declined during 2008-19.

SOURCE: MARSH



Deterioration in refining engineering standards (each circle represents the average score for the respective four-year period).

Sub Topic	Best In-Class Performance
Engineering standards used	Company has its own published or adopted standards in excess of major contractor standards, and these are regularly revised/updated. Company has representation on international standards committees. Regular symposia held by company.
Specific loss prevention standards	Company has its own process safety management system and work processes, which are regularly updated and address the specific hazards of the plant. Regular symposia held by company.
Natural perils protection	All aspects are considered and documented, for example: • Flooding • Wind • Rainfall/storms • Earthquake • Electrical storms • Tidal waves
Process hazard analysis (PHA)	Company has an active PHA program with a minimum scope and frequency in line with international standards. PHA review is embedded in change-management process.
Safety case	High-quality submission that exceeds government standards and is third-party verified.

In essence, external standards represent a minimum expectation, and the highest-scoring sites demonstrate commitment, rather than just compliance, through the development and application of their own standards.

For both gas processing plants and terminals/distribution, Marsh risk-ranking data indicates there has been an overall deterioration in risk quality across all measured areas (hardware, software, and emergency response) over the past 12 years.

US$
100M

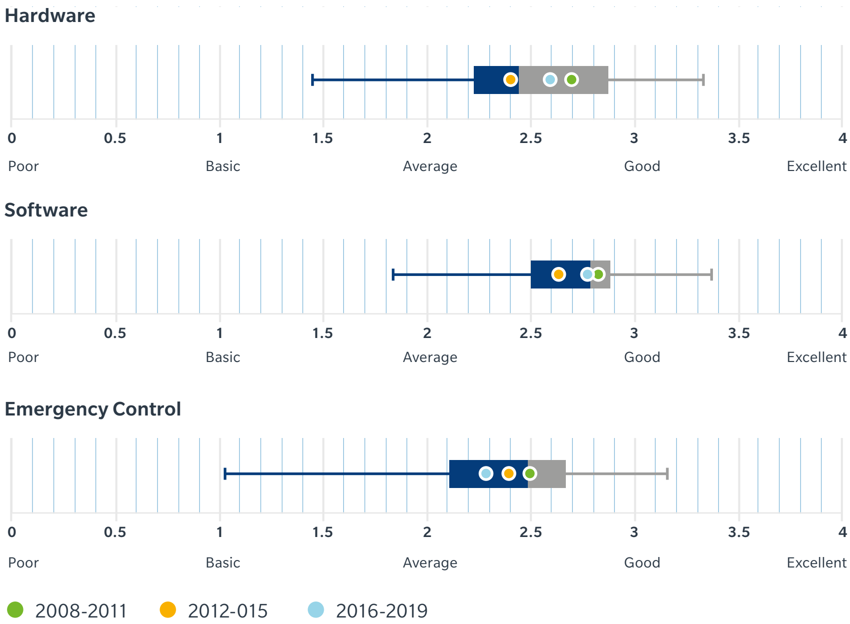
The onshore oil and gas sector has recently experienced more property damage losses per annum in excess of US$100 million.

For both gas processing plants and terminals/ distribution, Marsh’s data indicates there has been a deterioration in risk quality.

FIGURE 4

Overall risk quality in terminals/distribution deteriorated during 2008-19.

SOURCE: MARSH

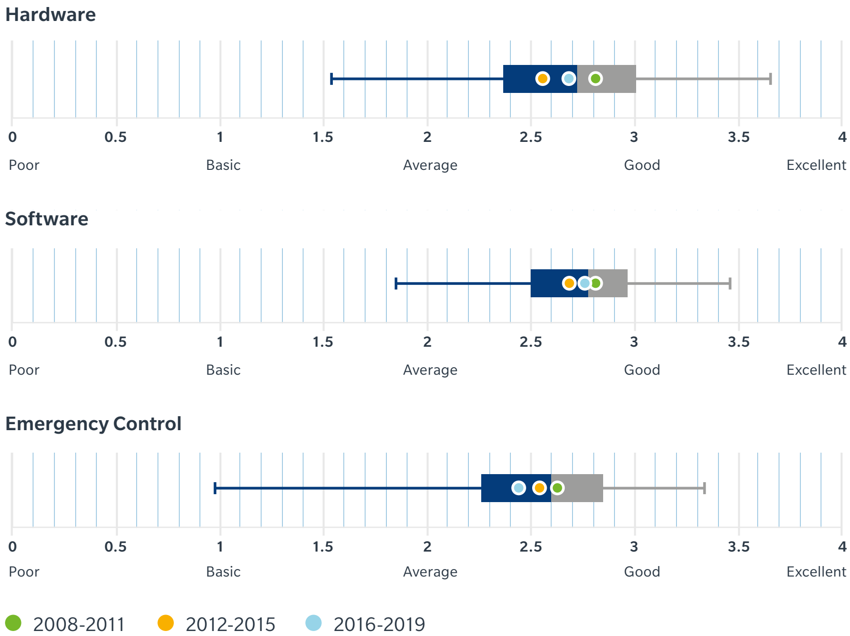


Deterioration in global risk ranking for terminals/distribution (each circle represents the average score for the respective four-year period).

FIGURE 5

Overall risk quality in gas processing plants deteriorated during 2008-19.

SOURCE: MARSH



Deterioration in global risk ranking for gas processing plants (each circle represents the mean score for the respective four-year period).

These two categories make up a relatively small portion of the 100LL, due to their relatively lower concentration of value than refineries/petrochemical plants. However, there have still been large property damage losses in these sectors over recent years. For example, a fire at a tank farm in the US, in March 2019, resulted in the destruction of at least 12 of the 15 tanks on-site, and property damage amounting to roughly US$125 million.

Although it is not possible to accurately forecast the number and scale of future losses, these findings raise the question of whether we will continue to see increased frequency of losses unless swift action is taken.

Lessons Learnt

The past two years have seen several major losses from refineries and petrochemical assets, particularly those of at least 50 years in age. One contributing factor might be the observed reduction in global "engineering standards" at refineries over the past 12 years, which, in the case of the US, has been coupled with a shift towards lighter regulation. Reduced regulation will always disproportionally affect higher-risk sites that simply comply with requirements, rather than the most mature sites with a strong commitment to process safety. Another factor in the loss history might be the recent oil price and consequent continued higher utilization of refineries.

Although not as prevalent in the 100LL, terminals/distribution and gas processing plants have also experienced large losses. This is perhaps not surprising, given the overall deterioration in risk quality observed over the past decade. This degradation may also prove to be a leading indicator of increased losses in the near future.

The very best sites, with the most mature process safety cultures, have consistently shown it is possible to run a facility without losses across the duration of their lifespan, and across a range of external regulatory standards and oil prices. It is vital the industry heeds the warnings, understands the lessons, and embeds the learnings contained within the 100LL. Otherwise the worst years may not be behind us.

US$
125M

The size of the property damage loss resulting from a fire at a tank farm in the US, in March 2019 — resulting in the destruction of at least 12 of the 15 tanks on-site.

CHAPTER 2

30 Years on: Is History Repeating Itself?

US$
2,088M

The Piper Alpha explosion in the North Sea, UK, 1988 — the largest industry property damage loss of all time.

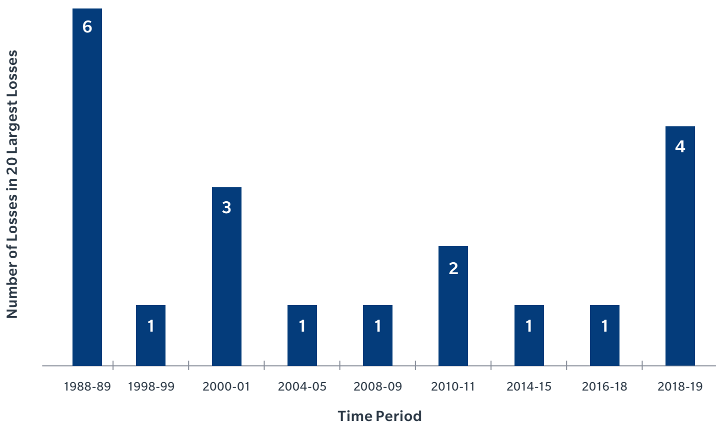
30 Years on: Is History Repeating Itself?

The past two years have contributed more incidents (four) to the top-20 largest losses than any other two-year window for 30 years. Not since 1988-89 (when six of the largest losses occurred), has there been such a high concentration of large losses.

FIGURE 6

An unusually high number of large losses occurred in 1988-89 and 2018-19.

SOURCE: MARSH



Thirty years on, it is worth reflecting on the major contributing factors for these very large losses, and how they compare with recent events.

FIGURE 7

Large losses from 2018-19 were less numerous and severe than those 30 years earlier.

SOURCE: MARSH

1988-1989		2018-2019	
Loss Value (US$m)*	Location	Loss Value (US$m)*	Location
2,088	Piper Alpha, North Sea, UK	800	Jiangsu, China
1,615	Pasadena, Texas, US	750	Philadelphia, US
957	Gulf of Mexico, US	650	Wisconsin, US
811	Campos Basin, Brazil	600	Limbe, Cameroon
737	Nevada, US		
708	Louisiana, US		

*On basis of December 31, 2019.

Largest Losses in 1988-1989

It is instructive to differentiate between root causes and escalating factors, which can be considered as the two sides of a bow-tie diagram: Root causes, if eliminated, would have avoided the event altogether; escalating factors would have prevented the event from growing to such magnitude.

ROOT CAUSES

Systems of work

This includes permitting, management of change, and shift handover. There were shortcomings in each of these three areas for the Piper Alpha incident (where there was a release of condensate and subsequent explosion following the reinstatement of a pump that had been out for maintenance, due to gaps in control of permits and information transfer during handover. The incident was exacerbated by the original platform being designed for oil rather than gas processing). There were key issues associated with permitting for maintenance work at the Pasadena petrochemical plant (an accidental release of polyethylene resulting from inadequate isolation during routine maintenance), and the Gulf of Mexico incident (release of hydrocarbon during the installation of a pig trap on an export gas pipeline), and also with management of change for Campos Basin (explosion during the conversion of a platform well from oil to gas production).

Inspection

This includes internal corrosion on the FCC unit at Louisiana, resulting in a loss of primary containment of propane, which caused a large vapor cloud explosion.

ESCALATING FACTORS

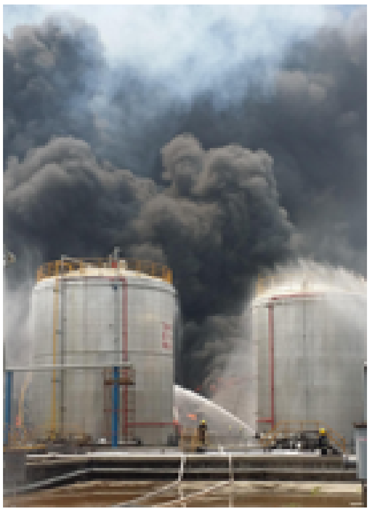
Emergency response plan (ERPs)

The lack of adequate ERPs caused the initial incidents to escalate at Piper Alpha (the platform evacuation plan relied largely on the use of a helipad, which was inaccessible due to the smoke from the fire, and nearby multi-function support vessel struggled, having never been tested in such extreme conditions); while at Campos Basin it took over a month to control the resulting fire, compounding the cost of the incident.

Fire protection

At Piper Alpha the fire-water system was in manual prior to the incident, due to divers being in the water, and this contributed to the incident. At Louisiana the refinery immediately lost all utilities, including fire water and the four diesel fire pumps, greatly limiting the firefighting effort for several hours. At Pasadena there was no dedicated fire-water system, instead the process water system was relied upon, which lost pressure following the explosion. The fire-water pumps failed when the resulting fires damaged electrical cables and, of the three standby diesel pumps, one was under maintenance and another ran out of fuel.

There were shortcomings in permitting, management of change, and shift handover for the Piper Alpha incident.



US$
800M

The explosion in Jiangsu, China — the largest petrochemical property damage loss since Pasadena 1989.

Largest Losses in 2018-2019

For the most recent incidents, the loss data is less readily available and in some cases investigations are still ongoing; however, comparisons can still be drawn with the events 30 years ago.

ROOT CAUSES

Inspection

At Philadelphia, it is thought that the rupture of a thinned pipe elbow installed around 1973 was the initiating event, which caused the major loss of primary containment, resulting in a large fire and subsequent explosions.[1] At Wisconsin it is believed that the root cause was an FCCU spent catalyst slide valve, which was intended to be "provided with erosion protection suitable for the design life at the design conditions," but had actually eroded and was unable to maintain the catalyst level required to prevent air from mixing with hydrocarbons during transient operation.

Engineering standards

The ruptured Philadelphia pipe was reported to contain levels of copper and nickel that were permitted when it was originally installed, but not under recommendations made 20 years later by the American Society for Testing and Materials (ASTM International).[2] Although standards had moved on, the equipment at the plant reportedly had not.

ESCALATING FACTORS

Fire protection

The incident at Limbe began as a fire near a distillation unit on the refinery, which escalated to a much larger explosion. More robust fixed-fire protection at site may have reduced or prevented this escalation.

Emergency response plans

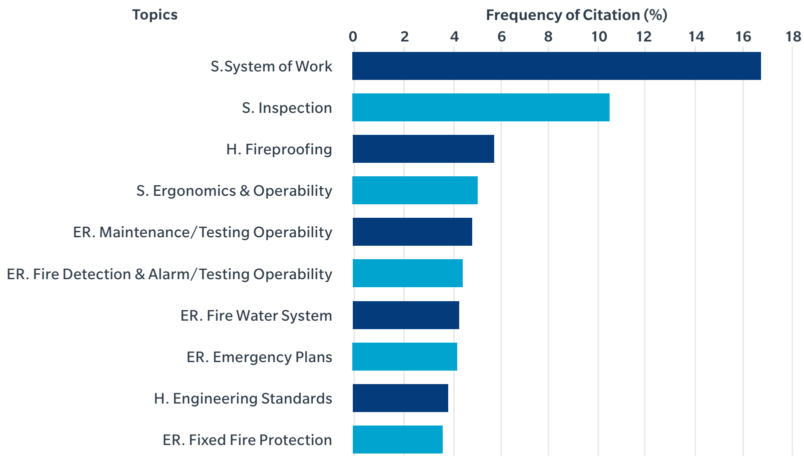
In all four incidents, the sites were not well prepared for the incidents that occurred. Carefully considered and documented emergency plans, which are tested through drills on a regular basis, can help to greatly reduce the eventual impact of an event from the point at which it is initiated.

The most commonly cited risk recommendation topics by Marsh over the past few years (see chart below), reinforce the view that the same issues are still observed today as they were in 1988-1989.

FIGURE 8

Systems of work was the most frequently cited topic.

SOURCE: MARSH



[1] U.S. Chemical Safety and Hazard Investigation Board, *Fire and Explosions at Philadelphia Energy Solutions Refinery Hydrofluoric Acid Alkylation Unit.*

[2] Ibid.

Barriers to Learning from Losses

Four key factors prevent lessons from being learnt from losses, and allow history to repeat itself:

Distance
Regulation following a major incident is often enforced locally rather than globally, and consequently only, or at least mostly, affects local awareness. At the same time, parties can be affected by closeness bias — feeling unconsciously less affected by events a long way away.

Culture
This can prevent lessons from being implemented effectively. Fear of litigation/blame prevents open reporting of incidents and learnings within organizations, while difficulty challenging upwards in certain cultures can prevent improvements being implemented.

Tunnel vision
Some companies do not realize wider relevance of lessons. Siloed thinking can cause companies to imagine that an incident happening in a different type of facility from their own does not provide applicable learnings.

Time
Lessons have been learnt, but have since been forgotten or solutions implemented are insufficiently robust. Given the 30 years that have elapsed between the two-worst periods in terms of the 20-largest losses, this would seem to be particularly significant. The lapse of time can result in the following:

- Loss of experienced people.
- Loss of corporate memory — efficacy of safeguards put in place following large losses eroded over time.
- Lack of understanding how risk can change with the age of plant, including:
  - Creeping or subtle change that is not recognized.
  - Inherited problems if site changed ownership.
- Complacency — "Has worked fine for 20 years" — it can be challenging to maintain focus in the workforce over several decades.

The industry must ensure that in 30 years' time, we are not reflecting that the lessons have still not been learnt. This will only be achieved with a continued focus on process safety, and a commitment to learn from losses at all levels of an organization.

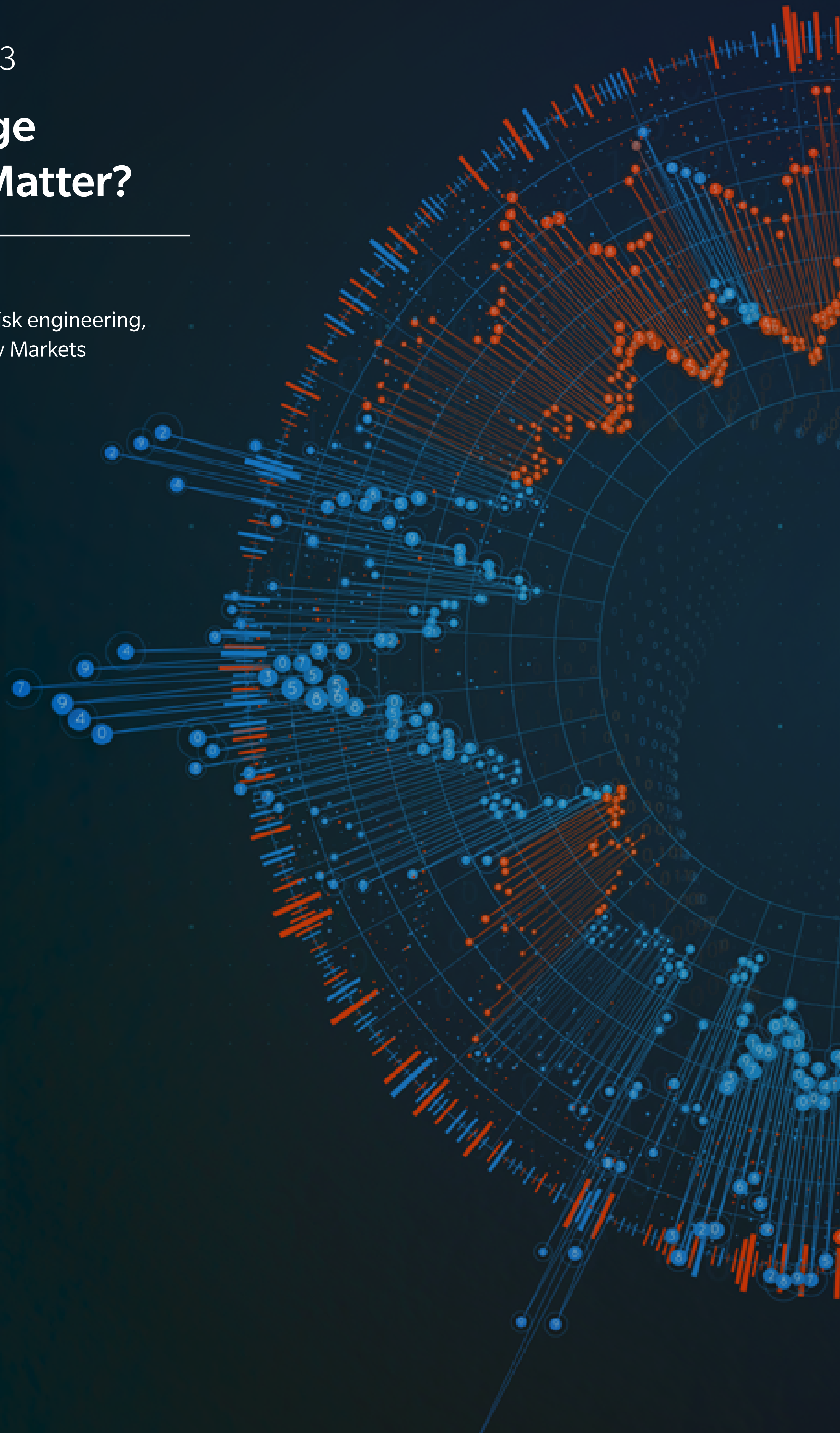
Siloed thinking can cause companies to imagine that an incident happening in a different type of facility does not provide applicable learnings.

CHAPTER 3

Does Age Really Matter?

IAN ROBB

Global head of risk engineering,
Liberty Specialty Markets



Does Age Really Matter?

IAN ROBB

Global head of risk engineering, Liberty Specialty Markets

Ian Robb is the global head of risk engineering for Liberty Specialty Markets, and based in London. He is a chartered chemical engineer, responsible for global risk engineering activities in support of Liberty's underwriting and claims teams within the energy, property, heavy industry, and construction product lines.

Property damage loss data and trends discussed in this article have been extracted from the Liberty Specialty Markets oil & gas loss database, which has captured and analyzed the cause of loss for the onshore oil and gas sector since 2000. Excluding natural catastrophe events, the database has over 700 losses and serves as a valuable source of insight that supports Liberty's underwriting decisions.

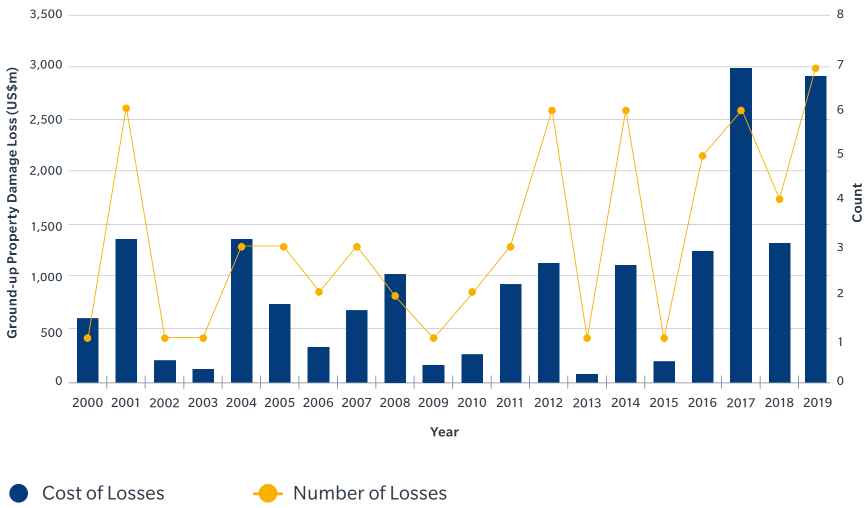
With plants older than 30 years far more likely to experience losses, the industry needs to look more closely at the risks of older refineries and petrochemical plants.

The onshore oil and gas sector has recently experienced a rise in the number of property damage losses per annum in excess of US$100 million. The period 2016-2019 was particularly poor, with property damage losses well in excess of US$300 million occurring at refineries in North America and Europe, all of which were originally built in the 1960s or earlier.

FIGURE 9

The number and total cost of property damage losses have both risen in recent years.

SOURCE: LIBERTY SPECIALTY MARKETS



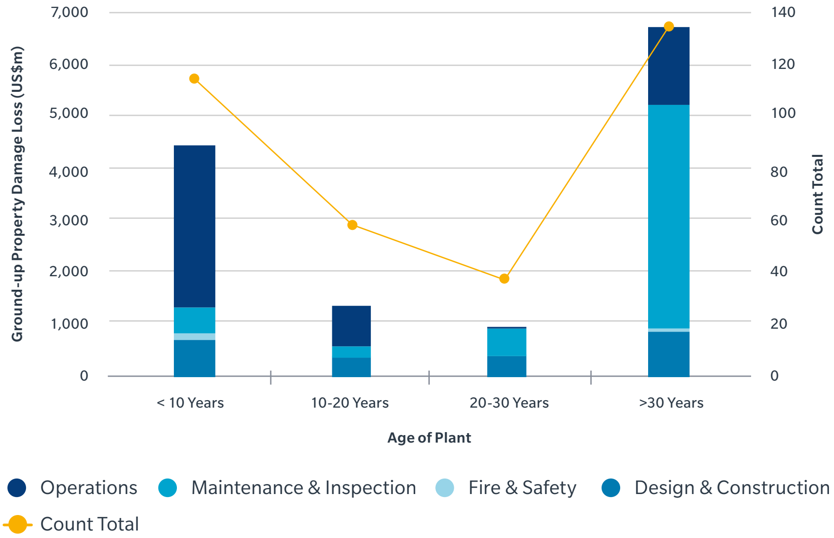
In the first 10 years of a plant's operation, most losses are caused by operations-related failures, such as not following operating or permit-to-work procedures (see figure 10). As plant operations experience develops, the number of losses reduces, until age takes its toll and there is a steep rise in both loss frequency and magnitude in plants more than 30-years-old, creating a skewed "bath-tub curve."

In older plants, mechanical-integrity-related failures account for 65% of losses. Failure of piping becomes increasingly more prevalent as plants age. (Overall, not accounting for age of plant, piping failure accounts for 60% of mechanical integrity losses.)

FIGURE
10

Plants older than 30 years see most losses, with maintenance and inspection failures the primary cause.

SOURCE: LIBERTY SPECIALTY MARKETS

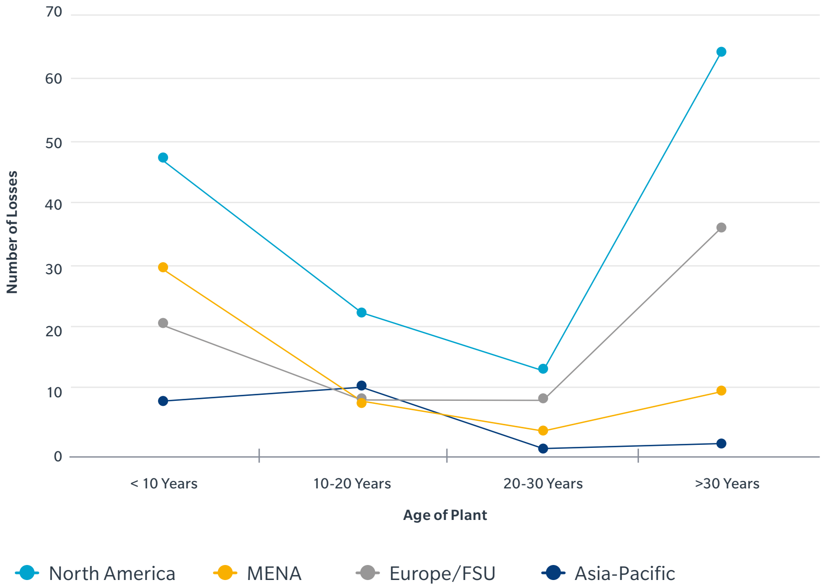


The largest number of losses have occurred in North America (see figure 11) followed by Europe, Middle East/North Africa (MENA), and Asia-Pacific (excluding China).

FIGURE
11

North America experiences the largest number of losses, which follow a "bath-tub" curve.

SOURCE: LIBERTY SPECIALTY MARKETS



The MENA and Asia-Pacific regions do not yet follow the traditional "bath-tub curve," primarily due to the younger age of their operating plants compared to Europe and North America, which have similar shapes. As plants in the MENA and Asia-Pacific regions age, we may see similarly shaped "bath-tub curves" develop.

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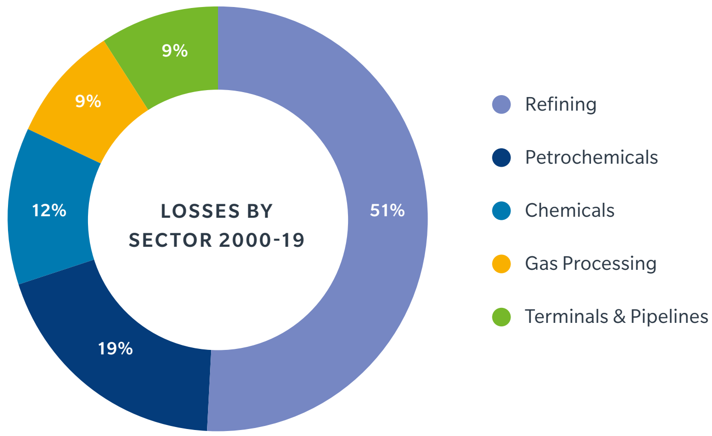
The oil sector, principally refining, is the major industry contributor to major losses.

The oil sector, principally refining (including Canadian Oil Sands), is the major industry contributor to major losses (constituting 51% of all losses — see figure 12), with the petrochemicals sector a distant second place (19%). This can at least partly be attributed to the highly corrosive nature of crude feed-stocks and processes, which presents challenges both to ensure that metallurgy is up to current standards and for inspection departments.

FIGURE 12

Refining accounts for more than half of all losses during 2000-19.

SOURCE: LIBERTY SPECIALTY MARKETS



To draw any conclusions from a regional analysis, it is necessary to examine the size of the refining fleets currently operating in those regions and their respective age. Out of a current global operating refinery fleet of 652, there are 142 in North America, and 137 in Europe/FSU, according to data from data provider Global Data — so similar size fleets overall.

In terms of age distribution, it is harder to provide an exact correlation. However, one measure to consider is the year in which each region achieved a benchmark of 50 operating refineries. For the US, this was 1930; Europe/FSU — 1955; Asia-Pacific (excluding China) — 1976; and MENA — 1999.

There is a much higher incident rate for North America than for, say, the Asia-Pacific region. Allowing for the difference in size of regional refinery fleets, it can be concluded that North America has the oldest refineries globally, highest utilization rates, and also the highest Nelson Complexity Index. These high-conversion refineries typically process more corrosive crudes at more severe conditions and therefore operate in a more challenging regime, often while also coupled with higher throughputs.

FIGURE
13

The incident rate is higher in North America than other regions.

SOURCE: LIBERTY SPECIALTY MARKETS

Region	Refinery Loss Frequency
North America	2.82×10^{-2}
Europe/FSU	2.03×10^{-2}
Middle East/North Africa	1.89×10^{-2}
Asia-Pacific	1.42×10^{-2}

In summary, in order to prevent losses involving aging plant and equipment increasing, implementation of an effective mechanical integrity program is vital. Ensuring best practice metallurgy to current industry standards, inspection programs designed by qualified inspectors and corrosion engineers, along with accredited qualifications of those conducting inspections are all essential requirements.

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CHAPTER 4

Organizational Resilience: Turning Uncertainty into Opportunity

Many energy companies' business resilience strategies continue to lag.

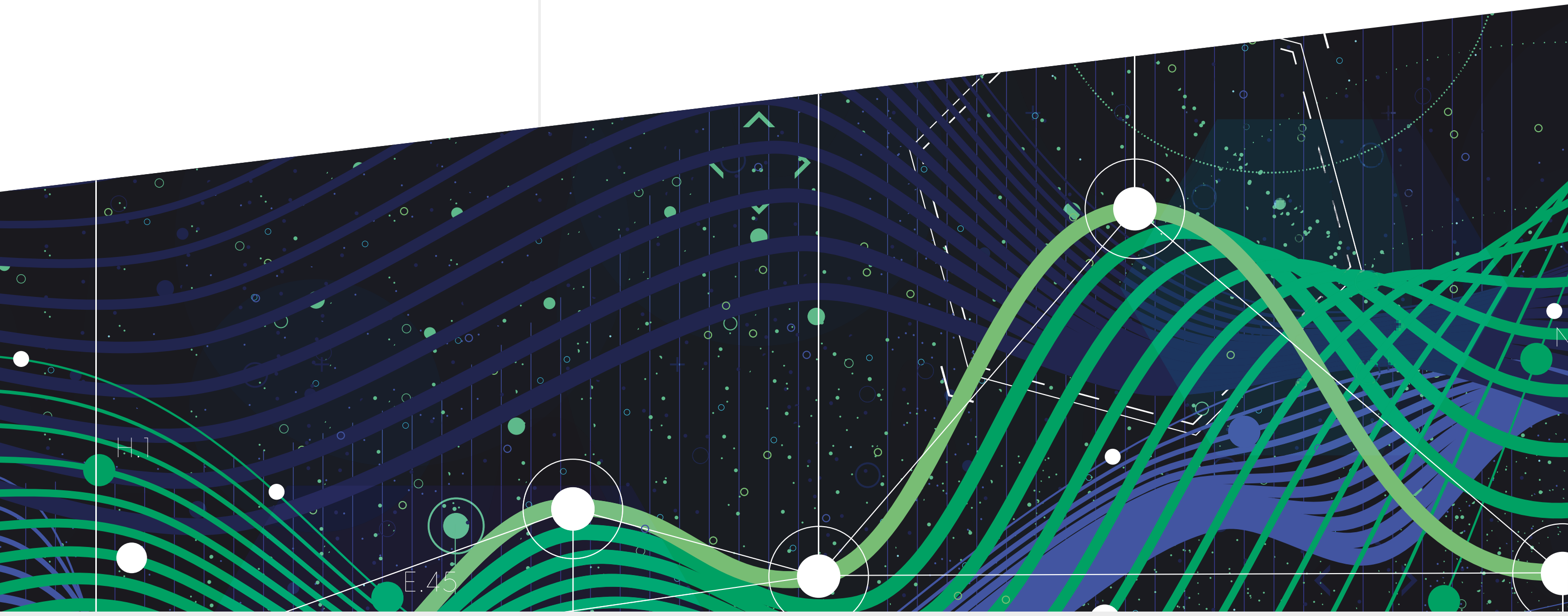
Organizational Resilience: Turning Uncertainty into Opportunity

With plants older than 30 years far more likely to experience losses, the industry needs to look more closely at the risks of older refineries and petrochemical plants.

The past two years have seen a high number of large property damage losses across the energy sector. Such losses can take a long time to recover from and can even mark the end for a site. For example, the reported US$750 million loss in June 2019, at a refinery in Philadelphia, resulted in the refinery closing shortly afterwards and the operator ultimately filing for bankruptcy.

Business continuity and business interruption strategies are vital to mitigating an event's knock-on effects, costs, and ultimate severity. Yet many energy companies' business resilience strategies — including their investment and implementation — continue to lag. Some companies have mature emergency response functions, and business interruption coverage, but have no formal procedures or plans relating to crisis management, business resilience/continuity planning, or cyber resilience.

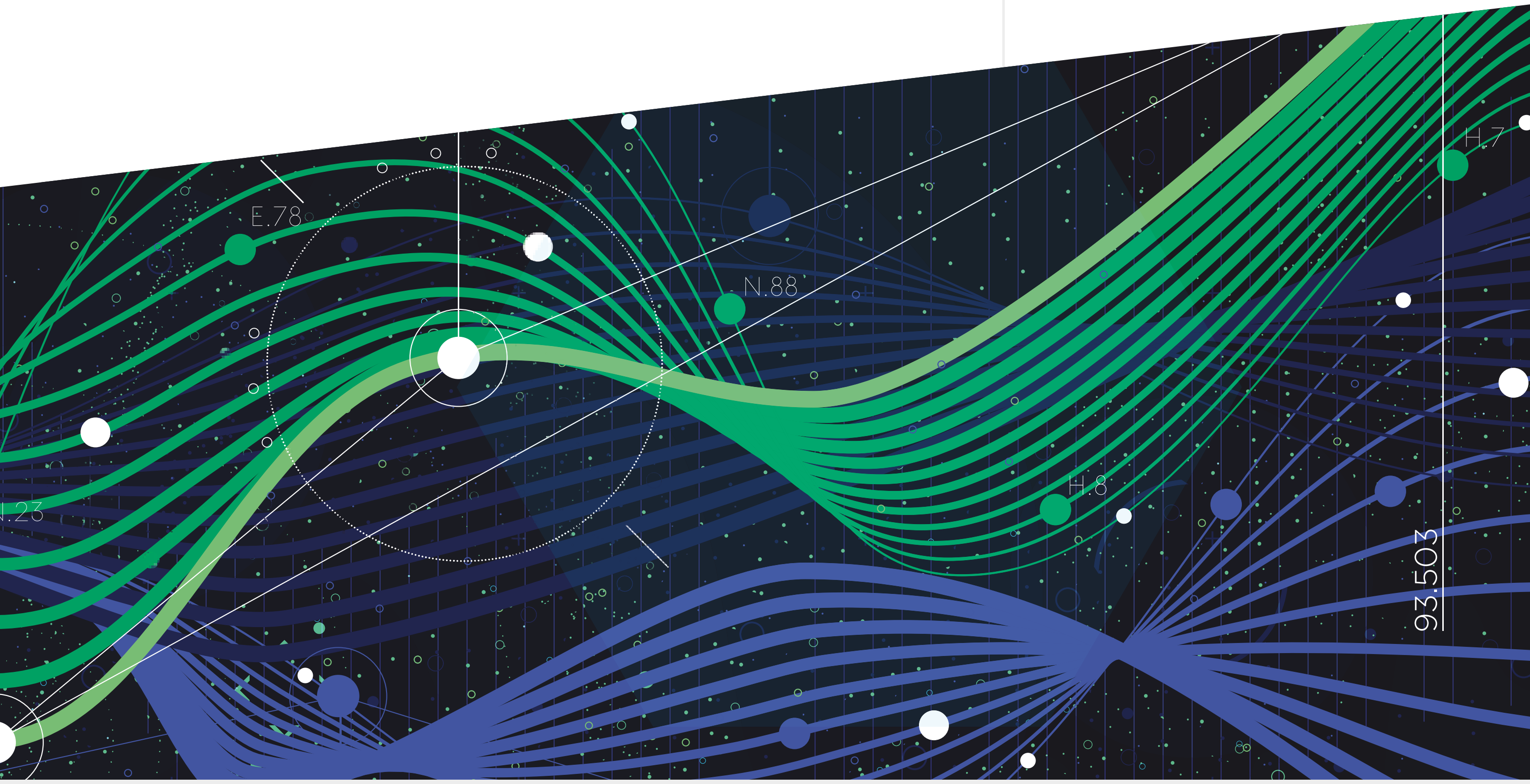
A 2018 Marsh study explored share and stock price volatility — over a 250 trading-day, post-incident timeline — for a sample of listed companies that experienced high-profile incidents in the past 10 years. All the companies received significant business and financial media coverage. The findings showed that post-crisis, some companies can benefit from a sustained 5% increase in share performance, while others lose on average 12% of their value. The main reason for this difference? A holistically implemented crisis management and incident response plan.



Implementing a risk and resilience program that anticipates, prepares for, responds to, and adapts to internal and external events, regardless of the cause, requires the following key attributes:

- Overall management commitment to and sponsorship of the organizational resilience program.
- Strategic involvement of internal and external stakeholders in resilience and business continuity, including supply-chain resilience.
- Proactive identification and control of risks.
- Flexible and agile supply chains, with sufficient alternative arrangements built in to support fast changes to operating structures and processes.
- Proactive management of internal and external communications, including media response planning for post-crisis situations.
- Swift control of the situation — including taking ownership of the problem and the solution, decisiveness, and being able to admit mistakes during crisis management.
- Transparent, honest, and frequent communication with stakeholders to build confidence.
- Strong alignment between emergency response, crisis management, business continuity, IT disaster recovery, IT, and operational technology cyber response plans.
- Continuous improvement by embedding lessons learned.

Post-crisis, some companies can benefit from a sustained 5% increase in share performance, while others lose on average 12% of their value.



CHAPTER 5

Graphics

FIGURE 14

The two largest-ever losses still date from the period 1988-89.

SOURCE: MARSH

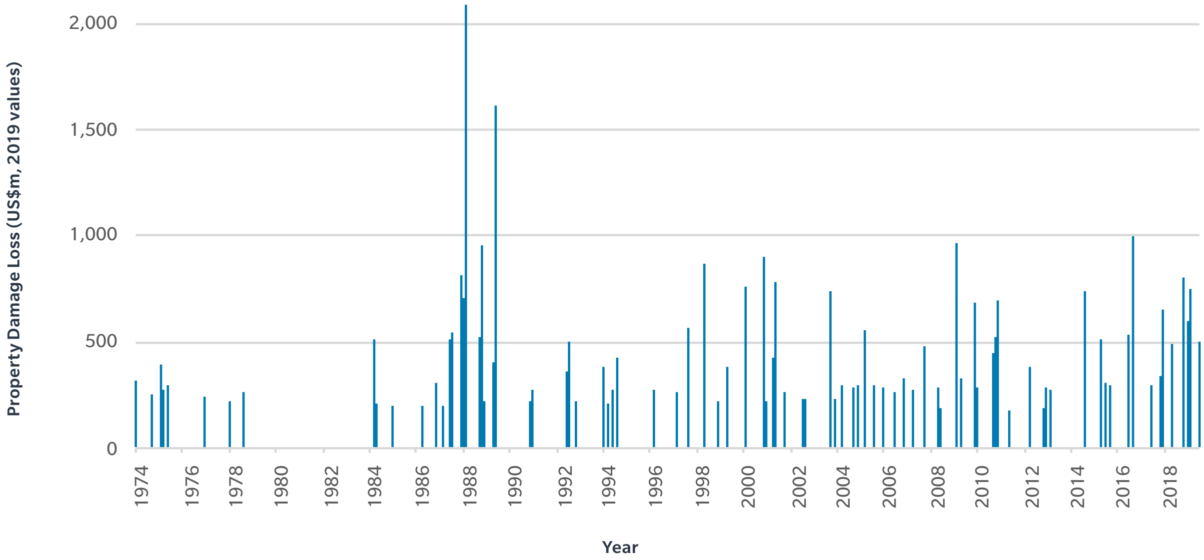
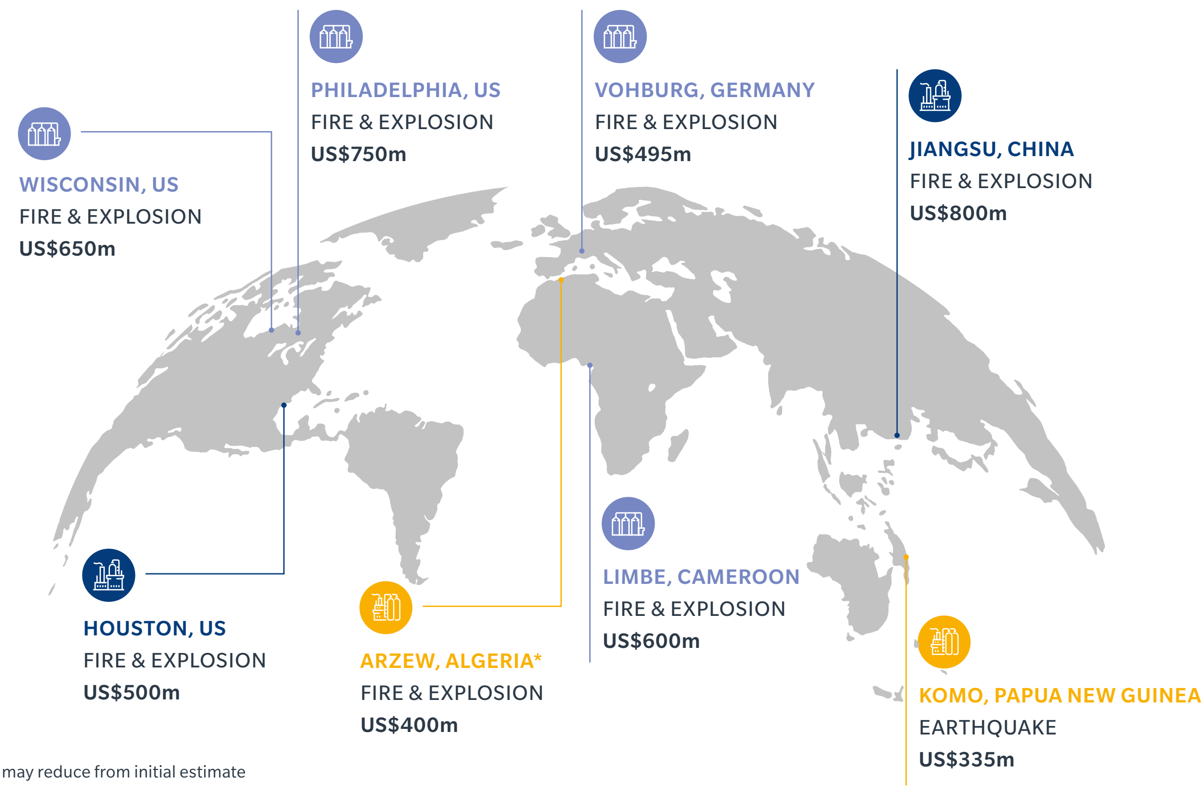


FIGURE 15

Recent large losses occurred across the world.

SOURCE: MARSH



*Loss value may reduce from initial estimate as further information becomes available.

FIGURE 16

Refining accounts for more than a third of 100LL during 1974-2019.

SOURCE: MARSH

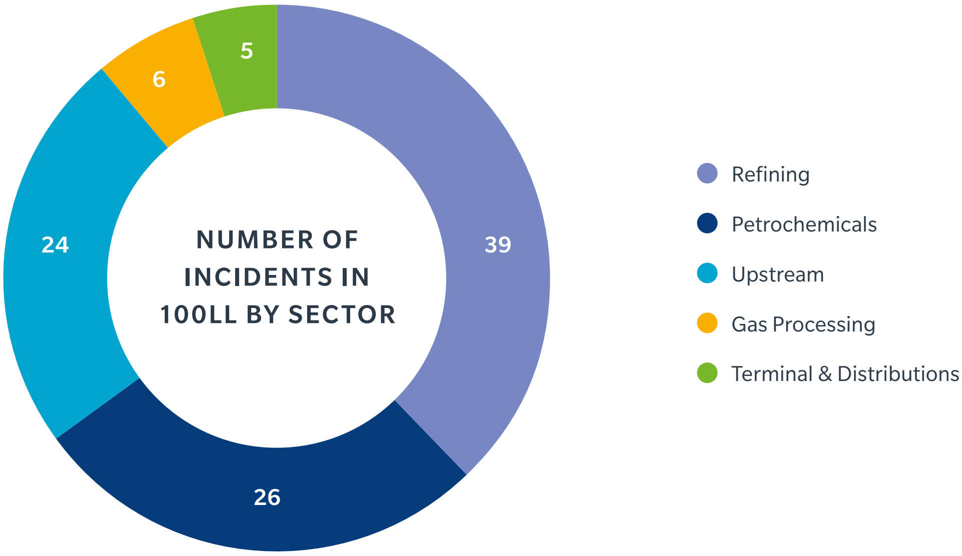


FIGURE 17

Upstream accounts for an inordinate number of very high-value losses during 1974-2019.

SOURCE: MARSH

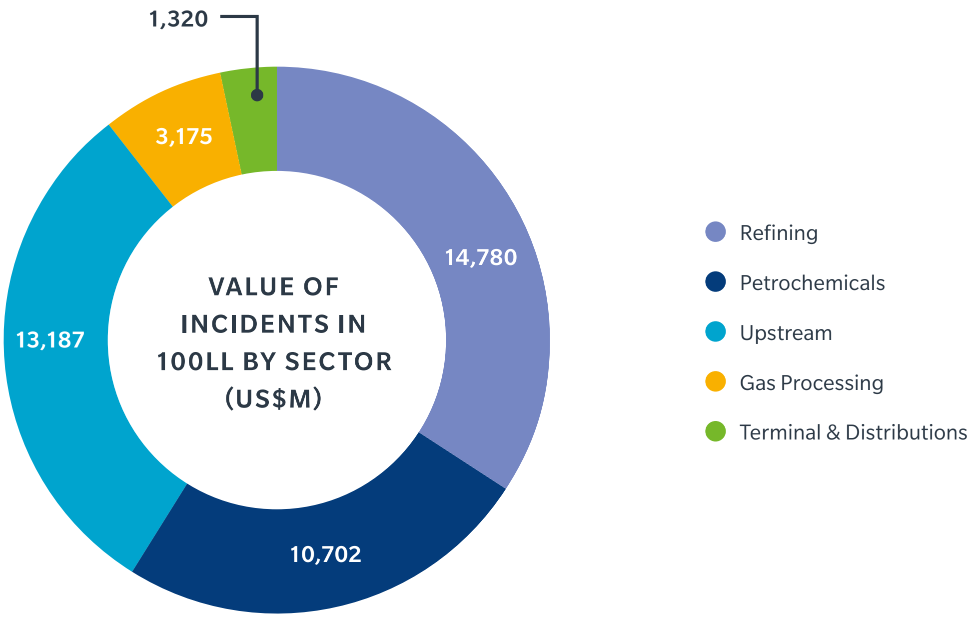
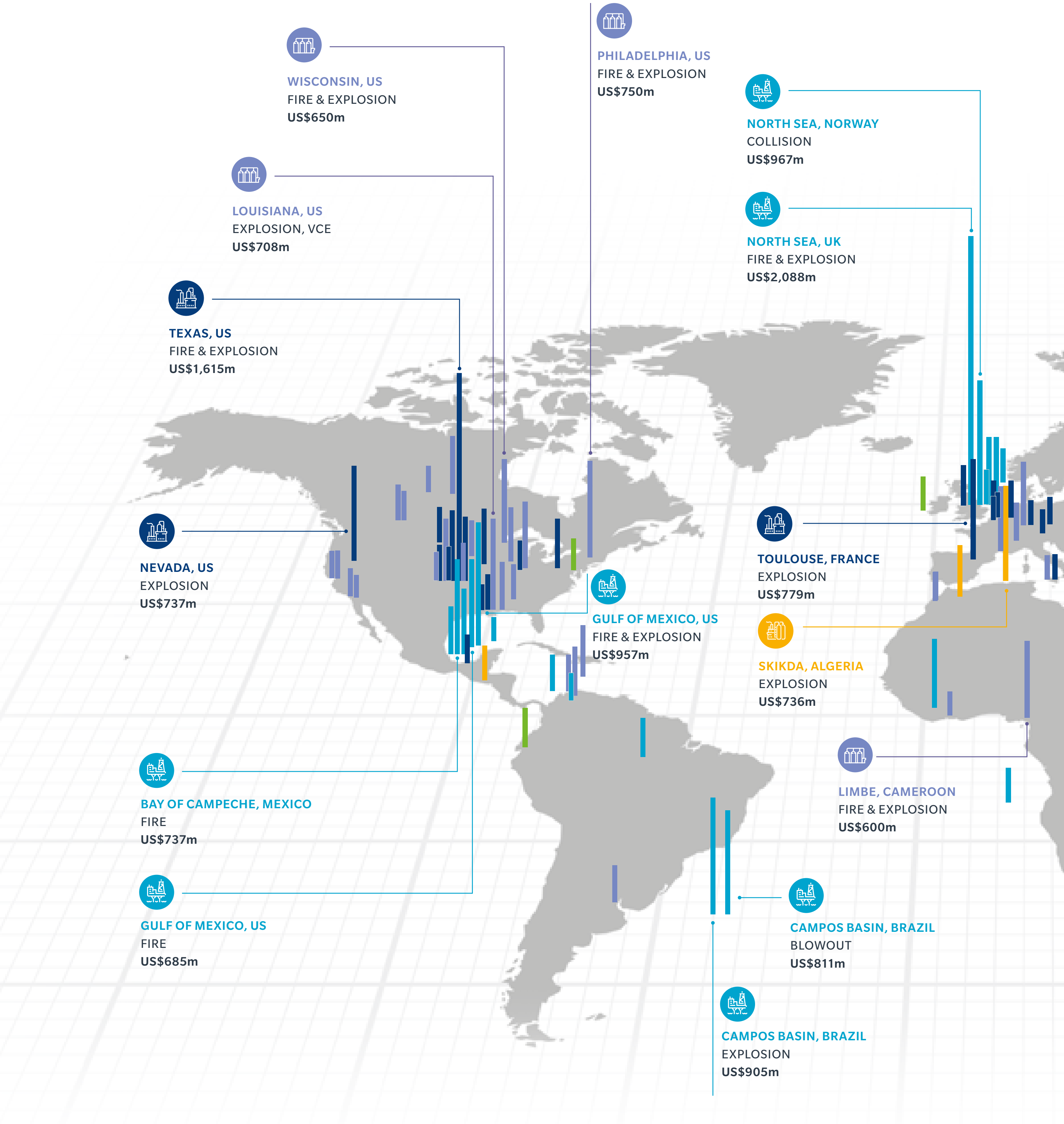


FIGURE 18

Most 100LL occurred in North America or Europe.

SOURCE: MARSH



Each figure included in this chart denotes the property damage loss, adjusted to 2019 values.

CHAPTER 6

100 Largest Losses Descriptions

Three quarters of recent property damage refinery losses in excess of US$100 million occurred at sites built in the 1960s or earlier.

Refineries

There have been a number of large refinery losses over the past two years. Four losses were large enough to qualify for the 100LL (for which the threshold is US$175 million), and several more were in excess of US$100 million. This is a continuing trend since the early 2000s and refinery losses now make up 39% of the 100LL.

The worldwide group of oil refineries is, with some notable exceptions, a group of aging assets, and 75% of recent property damage losses in excess of US$100 million occurred at sites built in the 1960s or earlier. Older assets have often been subject to both expansion projects to increase capacity, and retrospective installation of high-value, high-conversion assets; together these have resulted in higher concentration of value at sites.

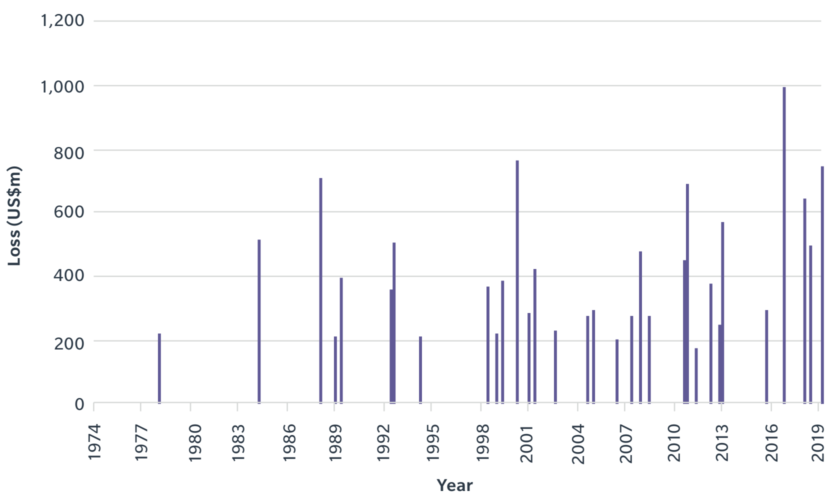
Refineries process crude oil and therefore have a far more dynamic and broad feedstock range than the other asset classes. Many sites also push their crude oil processing envelopes to maximize operating margin: Relatively low crude oil prices in recent years have contributed to positive refining margins, in turn resulting in high global refinery utilization.

The combination of aging assets, increased concentration of value, and diverse feedstocks are likely to have contributed to the increasing frequency and magnitude of losses in this sector.

FIGURE 19

Large refinery losses have become more frequent since 2000.

SOURCE: MARSH



ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

1,000+M / 1,000M

UAE | 01/11/2017

A release of hot light hydrocarbon during the completion of a maintenance activity resulted in a major fire. The fire occurred on a residual fluid catalytic cracking (RFCC) unit that had recently been commissioned as part of a major expansion, doubling the overall refinery capacity. The fire resulted in the closure of the expanded area of the refinery while extensive rebuilding activity was delivered.

766M / 412M

MINA AL-AHMADI, KUWAIT | 06/25/2000

The explosion occurred when employees were attempting to isolate a leak on a condensate line between an off-site NGL plant and the refinery gas plant. Three crude units were damaged and two reformers were destroyed. The fire was extinguished approximately nine hours after the initial explosion. Five people were killed and 50 others were injured. The investigation into the loss indicated a lack of inspection and maintenance of the condensate line, which was not owned by the refinery. Lack of clear understanding of the ownership of the line is thought to have delayed the isolation of the line.

750M / 750M

PHILADELPHIA, US | 06/21/2019

A major loss of primary containment on the hydrofluoric acid alkylation unit at the refinery resulted in a large fire and subsequent explosions. It is thought that the rupture of a thinned pipe elbow installed around 1973 caused the process fluid release. The refinery closed shortly after the incident and the operator filed for bankruptcy.

708M / 288M

NORCO, LOUISIANA, US | 05/05/1988

Operations were normal in a 90,000 bbl/d fluid catalytic cracking (FCC) unit, when internal corrosion caused the failure of the outside radius of an eight-inch diameter carbon steel elbow, located 50 feet above grade in the depropanizer column overhead piping system. An estimated 20,000lb of C3 hydrocarbons escaped through the resulting hole, forming a large vapor cloud during the 30 seconds between failure and ignition. Both the depropanizer column (operating at 270 psi and 130 °F) and the depropanizer accumulator depressurized through the opening. Ignition of the vapor cloud was probably caused by the FCC charge heater.

The initial blast destroyed the FCC control building and toppled the 26-foot diameter main fractionator from its 15-foot high concrete pedestal. The column separated from its 10-foot high skirt before falling. Analysis of bolt stretching of towers in the blast path indicated over pressures as high as 10 psi.

The refinery immediately lost all utilities, including fire water and the four diesel fire pumps, greatly limiting the fire-fighting effort for several hours. Steam pressure dropped abruptly due to severed lines. Twenty major line or vessel failures occurred in the FCC and elsewhere throughout the 215,000 bbl/d refinery. Blast damage throughout the plant was extensive, but was most severe in the FCC unit. About 5,200 property claims were received for off-site damage at distances of up to six miles. The FCC unit was eventually demolished and a new unit was constructed.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

A preliminary report stated that the failed elbow was located downstream of an injection point, where ammoniated water was added to reduce depropanizer condensation or fouling. The elbow was a designated inspection point in the overhead piping system for taking ultrasonic thickness measurements during turnarounds. These inspections had constantly shown the expected corrosion rates of 0.05 mils per year. Measurements taken at the failed elbow and in the downstream piping after the explosion revealed unexpected, high localized corrosion rates.

SENDAI, JAPAN | 03/11/2011

691M / 590M

A major explosion occurred at a 145,000 bpd refinery in the north-eastern city of Sendai, hours after the largest earthquake in the country's history was followed by a tsunami. The fire at the refinery originated from an oil product shipping facility. Workers at the refinery were being evacuated, and there was no capacity to extinguish the fire. Fire in the storage and shipping facilities resulted in damage to a 35,500 bpd fluid catalytic cracker (FCC) at the refinery.

WISCONSIN, US | 04/26/2018

650M / 650M

An explosion and subsequent fire at the refinery resulted in injuries to 36 people, and the evacuation of a large portion of the nearby town of Superior, Wisconsin. The incident occurred when the site fluid catalytic cracking unit (FCCU), was taken offline for planned maintenance.

It is believed that the FCCU spent catalyst slide valve had eroded and was unable to maintain the catalyst level required to prevent air from mixing with hydrocarbons during the transient operation. As a result, air flowed backwards from the regenerator into the reactor, and then into other downstream equipment — triggering a large explosion.

The explosion blew debris across the plant and one piece punctured a nearby large above-ground storage tank — resulting in the release of around 15,000 barrels of hot asphalt that subsequently ignited and caused a large fire.

LIMBE, CAMEROON | 05/31/2019

600M / 600M

A fire and subsequent explosion near the distillation unit on the refinery resulted in the whole site's shutdown, which is expected to last up to 12 months.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)* | ACTUAL PROPERTY DAMAGE LOSS (US$)

515M / 191M

ROMEOVILLE, ILLINOIS, US | 07/23/1984

Just prior to the rupture of a 55-foot-tall, 8.5-foot-diameter monoethanolamine absorber column, a refinery operator noted a six-inch-long horizontal crack at a circumferential weld that was leaking propane. As the operator attempted to close the inlet valve, the crack spread to about 24 inches. The area was being evacuated and the plant fire brigade was arriving when the column failed. Propane at 200 psig and 100°F propelled most of the 20 ton vessel 3,500 feet, where it struck and toppled a 138,000-volt power transmission tower.

The weld separation occurred along a lower girth weld joint made during repairs to the column 10 years earlier. The vessel was constructed of one-inch-thick ASTM SA 516 Gr 70 steel plates rolled and welded with full penetration submerged arc joints, but without post-weld heat treatment.

The explosion resulted in severe fires in the unsaturated gas plant, as well as fires in the fluid catalytic cracker (FCC) and the alkylation units. After about 30 minutes, a boiling liquid expanding vapor explosion occurred in a large process vessel in the alkylation unit. A piece of the vessel travelled 500 feet, shearing off pipelines before striking a tank in the water treatment unit. Another fragment landed in a unifining unit over 600 feet away, causing a major fire.

The first explosion, believed to be from a vapor cloud, broke windows up to six miles from the plant. The explosion also caused extensive structural damage to refinery service buildings and disrupted all electric power at the refinery, rendering a 2,500-US-gallons-per-minute (US gpm) electric fire pump inoperable. One explosion sheared off a hydrant barrel, resulting in reduced fire water pressure from the two 2,500-US-gpm diesel-engine-driven fire pumps, which were operating at the time. The refinery's blast resistant control center, approximately 400 feet northeast of the absorber, sustained little structural damage.

An estimated 30 paid and volunteer public fire departments, together with equipment from refineries and chemical plants within a 20 mile radius, responded promptly. Many of the pumpers took suction from the adjoining canal and from a quarry. The pumpers and a 12,000-US-gpm pump on a fireboat eventually provided water at pressures sufficient for fire fighting.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
504M	225M

LA MEDE, FRANCE | 11/09/1992

A vapor cloud explosion occurred in the gas plant associated with the 29,700 bbl/d fluid catalytic cracker (FCC) unit on a 136,000 bbl/d refinery.

The initial vapor cloud explosion and several subsequent lesser explosions could be heard in Marseilles, approximately 18 miles away. An estimated 11,000 pounds of light hydrocarbons were involved in the initial explosion.

A gas detection system in the FCC unit sounded an alarm indicating a major gas leak. While the unit operator was contacting the security service to warn of this situation, the initial explosion occurred. The initial gas release is believed to have resulted from a pipe rupture in the gas plant, which was used to recover butane and propane produced in the FCC unit.

The explosions and subsequent fires devastated about two hectares of the refinery, which covers about 250 hectares. The gas plant, FCC unit, and associated control building were destroyed by the incident. Two new process units, which were under construction and scheduled to come into operation in 1993, were seriously damaged. Roofs were damaged in the nearby town of Chateauneuf les Martigues and windows were broken within a radius of 3,000 feet. Some windows were broken up to six miles away.

The refinery fire brigade and over 250 firemen from three neighboring industrial sites and four nearby towns were used for more than six hours to bring the incident under control. Approximately 37,000 US gallons of foam concentrate were used during the fire-fighting effort. Some fires were intentionally left burning after the incident was under control to allow safe depressurizing of the process units, since the flare system was partially damaged by the explosions.

495M / 495M

VOHBURG, GERMANY | 09/01/2018

A hydrocarbon release occurred from a reactor vessel on a naphtha hydrotreater unit. The vessel operated at around 25 bar and 140 degrees C. The release of hot naphtha and hydrogen created a vapor cloud that ignited, leading to an explosion and fire. It is understood that the explosion caused further releases from other parts of the plant, including a nearby diesel hydrotreater, which contributed to the fire.

Eight on-site employees were injured, but there were no fatalities. Residents of a nearby town were evacuated as a precaution. Several hundred firefighters were reportedly deployed to control the fire.

Some refinery process units were extensively damaged as a result of the explosion and fire, as well as multiple office and maintenance buildings within the refinery site. Windows in a village at least 3km away were broken. The initial release of hydrocarbon was understood to have occurred as a result of a 1.5-meter crack that opened up in the reactor vessel. The root cause of the vessel failure is not yet fully understood.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
483M	380M
451M	385M
422M	233M

BIG SPRING, TEXAS, US | 02/18/2008

483M / 380M

An explosion at this 70,000 bbl/d oil refinery caused damage to the fluid catalytic cracker (FCC) utilities, storage tanks, and asphalt unit. An employee was hospitalized for burns, while another person was injured when her car was struck by debris from the explosion on the nearby highway. There were four injuries in total. Only 40 people were on-site because the explosion occurred on a public holiday (there would typically have been about four times as many people on duty). The fire was brought under control the same day by the site fire brigade, supported by local fire departments.

The release is believed to have occurred during a start-up on the propylene splitter unit, as a result of the catastrophic failure of a pump. Some processing resumed about two months later and the FCC was re-commissioned eight months after the incident.

FORT MCKAY, ALBERTA, CANADA | 01/06/2011

451M / 385M

An explosion occurred on an oil sands upgrader site north of Fort McMurray, Alberta. Five workers were injured in the blast, including one who received third-degree burns. A subsequent fire occurred at the top of one of the site's four coke drums and burned for nearly four hours. As a result, two of the coke drums were disabled. Workers returned to work to normal shifts the following morning. Most damage was sustained above the cutting deck and derrick infrastructure of the coke drum.

At the time of the incident the plant was operating on bypass conditions due to process upsets. An internal investigation team determined that the fire resulted from the opening of the top unheading valve on an active low-pressure coke drum. This allowed hot hydrocarbons to be released within the coker cutting deck building and was followed by ignition leading to the explosion and fire.

Exceptionally cold weather following the incident hampered efforts to gain access to the coker unit's cutting deck, due to the deluge protection in this area. Additional damage as a result of the fire fighting in freezing conditions also occurred.

LEMONT, ILLINOIS, US | 08/14/2001

422M / 233M

The 160,000 bbl/d capacity refinery was shut down due to a pool fire as a result of a pipework release on the crude distillation unit. Three days later the crude column suffered a structural failure due to an internal fire caused by air ingress from the previously ruptured pipework reacting with pyrophoric material and oil in the column. The crude distillation unit was shut down for 12 months. The cause of the initial pool fire was due to incorrect piping material specification in one elbow, which failed.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
399M	167M

ST CROIX, VIRGIN ISLANDS | 09/18/1989

Hurricane Hugo struck the refinery, causing extensive damage to 14 of the 500,000-600,000 bbl storage tanks in the tank-farm area, the administration building, and the company housing. The damage to process units, which were idled in preparation for the hurricane, was limited to the asbestos insulation on process columns and piping. A maximum wind speed of 192 mph was reported for the hurricane before the wind speed measuring device at the St. Croix airport was damaged.

Because of the damaged asbestos insulation, approximately 1,500 company employees and contractors worked every day for 15 weeks, to remove the asbestos debris from the refinery at a substantial extra expense.

385M / 200M

KORFEZ, GULF OF IZMIT, TURKEY | 08/17/1999

An earthquake measuring 7.4 on the Richter scale caused a collapse of a 312-feet-high concrete chimney on one of the crude units, setting off fires at the 226,000 bbl/d refinery. Fires also broke out on on-site storage tanks. The process teams successfully isolated and tackled the crude unit fire. Fires on the tank farm were allowed to burn themselves out after storage tanks were pumped out as much as possible. Due to broken water mains, fire-fighting efforts were limited to attempts by aircraft to drop chemicals on the fires. The US and many other countries sent foam supplies, personnel, and equipment to fight the fires. Damage to the refinery included a total loss of six storage tanks, while another four storage tanks were deformed, and 50% damage to other floating roof tanks. Damage to process units included the fire on the crude distillation unit, and damage to a reformer and several connecting pipelines.

382M / 330M

FALCON STATE, VENEZUELA | 08/25/2012

A powerful explosion occurred in an area of pressured propane and butane storage at the refinery. At least 48 people were killed and more than 80 injured. The explosion hit an area of storage tanks, damaging nine tanks. It was reported that there had been a significant number of leaks at the refinery in the previous year.

371M / 190M

PASCAGOULA, MISSISSIPPI, US | 09/01/1998

The entire refinery was shut down for three months after being struck by Hurricane Georges. The hurricane left the entire plant submerged under more than four feet of salt water from the Gulf of Mexico. Although the hurricane was only a Category 2 storm, its slow movement subjected the refinery to 17 hours of high wind and rain. The storm surge overtopped the dikes built to protect the refinery. Approximately 2,100 motors, 1,900 pumps, 8,000 instrument components, 280 turbines, and 200 miscellaneous machinery items required replacement or extensive rebuilding. Newer control buildings and electrical substations sustained little or no damage, as they had been built with their ground floors elevated approximately five feet above grade.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

361M / 161M

SODEGAURA, JAPAN | 10/16/1992

An explosion and subsequent fire resulted in significant property damage at the 146,500 bbl/d refinery. The explosion occurred following a heat exchanger failure in the hydrodesulfurization unit for light oil. The channel cover and lock ring of a breech lock closure type heat exchanger were hurled into an adjacent factory, which was located approximately 650 feet from the plant. The channel cover and lock ring were each five feet in diameter, and weighed 4,000lb and 2,000lb, respectively.

The hydrodesulfurization unit was being restarted following catalyst exchange work, when plant personnel noticed hydrocarbon being released from the heat exchanger. Plant personnel were working to complete the additional tightening work required on the heat exchanger bolts, due to thermal expansion, when the explosion occurred. The subsequent fire was brought under control in two hours, 45 minutes, by fire fighters using 15 fire trucks.

298M / 200M

TEXAS CITY, TEXAS, US | 03/23/2005

Fifteen people were killed and 105 injured following an explosion at the 460,000 bbl/d refinery. The explosion occurred in the isomerization unit, which was being restarted following its annual major maintenance turnaround. Loss of control of the restart of the isomerization unit resulted in one of the unit's splitter columns becoming full of light hydrocarbon. Eventually, hot liquid was released from the column through relief valves to a 30-meter-high blowdown stack on the unit. The release generated a large vapor cloud in the unit's vicinity. Some temporary buildings supporting planned turnaround activity on another unit were located near to the blowdown stack; many of the fatalities were attending a meeting in these buildings when the vapor cloud found a source of ignition and exploded.

298M / 250M

SANNAZZARO DE BURGONDI, ITALY | 01/12/2016

A major fire broke out on a refinery processing unit designed to convert heavy oil residues into refined products, resulting in serious damage to the plant.

288M / 159M

WICKLAND, ARUBA | 04/09/2001

An oil spill occurred due to a failure of a block valve to seat properly during maintenance on a pump strainer in the visbreaker unit. The oil auto-ignited and the ensuing fire spread and destroyed the visbreaker and damaged adjacent equipment. Subsequent explosions and heat restricted fire-fighting access; insufficient fire-brigade personnel, and damage to the firewater distribution system, further hindered extinguishing the fire. The fire was spread by the firewater application, and finally extinguished with help from the local fire department.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
280M	225M

LA PLATA DISTRICT, ENSENADA, ARGENTINA | 04/02/2013

A fire broke out in the 188,000 bpd refinery, caused by flash-floods during heavy rain. The rain overwhelmed the storm drainage system on the refinery, resulting in hydrocarbons being washed out of the drains and around the site. An explosion was reported in the crude distillation unit (CDU). There were two fires in the CDU, one in the coking plant, and two in the topping distillation plant. The government agency said the incident was caused by hydrocarbons exploding in one of the coke manufacturing furnaces, which had been shut but were still hot enough to ignite the hydrocarbon. It took eight hours to extinguish the fire and ten hours before the incident was under control. The oil company said there were no fatalities or injuries.

280M / 220M

TEXAS, US | 09/12/2008

The 365,000 bbl/d refinery sustained severe damage as Hurricane Ike passed through the Houston area, with related flooding due to storm surge as far away as Louisiana. Hurricane Ike had an unusually large storm surge, which inundated the refinery.

279M / 187M

FORT MCMURRAY, ALBERTA, CANADA | 01/04/2005

A fire broke out at the oil sands refinery in upgrader 2, an area of the plant that converts bitumen into crude oil products. Around 250 people were evacuated from the plant and no injuries were reported. The fire burned for nine hours before being extinguished. Witnesses reported two explosions minutes apart that sent a fireball six stories high into the air. The plant also suffered ice damage from water used to fight the fire, as temperatures in the area fell below -35 °C. A ruptured recycle line was the most likely cause of the fire.

272M / 200M

PASCAGOULA, MISSISSIPPI, US | 08/16/2007

A fire broke out in a crude unit number 2 of a 325,000 bbl/d refinery and burned for over six hours. No injuries were reported. Company officials said a major portion of the refinery was able to continue operating. The refinery's number 1 crude unit remained operational.

229M / 137M

FORT MCMURRAY, ALBERTA, CANADA | 01/06/2003

The incident occurred at an oil sands facility, with minor explosions occurring in the froth treatment plant. Damage appeared mainly limited to electrical cables in the solvent recovery area. The fire's cause appears to have been a hydrocarbon leak in piping. The plant's emergency response team was assisted by the local fire brigade, with the fire extinguished in two hours. Only one minor injury was reported. The incident occurred eight days after the new facility began operating.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
226M	130M
224M	55M
218M	113M
217M	120M

PORT OF MOHAMMEDIA, MOROCCO | 11/22/2002

226M / 130M

Following torrential rain, rising floodwater brought waste oil floating on the surface into contact with hot equipment on the refinery — causing explosions and a fire. A second blaze broke out and several storage tanks reportedly caught fire and exploded. Damage to the refinery was extensive and two people were killed, with a further three reported missing. Later reports said the fire had affected two or three production units. The processing units affected were 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. At the time it was stated that units unaffected by the fire would restart within 15 days, although other units would be inoperative for a further eight to twelve months.

TEXAS CITY, TEXAS, US | 05/30/1978

224M / 55M

A failure led to the release of light hydrocarbons that dispersed and found an ignition source. An intense fire followed in the tank farm. After less than five minutes, a 5,000 bbl storage sphere failed, resulting in a large fireball and rocketing pieces of the sphere 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, either as a result of missile damage or a boiling liquid expanding vapor explosion. Pieces of the tanks traveled in all directions, falling into various operating units and tank farms, starting more fires. Fragments also hit the firewater storage tank and electric fire pumps, leaving only the two diesel fire pumps operational.

RICHMOND, CALIFORNIA, US | 25/03/1999

218M / 113M

The explosion was caused by the failure of a valve bonnet in a high-pressure section of a 60,000 bbl/d hydrocracker. A vapor cloud formed from the release, ignited, and was followed by a large fire fed by escaping hydrocarbons at high pressure. The explosion resulted in the collapse of a large section of pipe rack and destruction of a large fin-fan cooler mounted above the rack. Many pumps were destroyed and a separator was badly damaged. Around 300 fire fighters and 33 fire trucks worked for two-and-a-half-hours to control the fire. Foam concentrate consumed totaled 3,200 US gal. The hydrocracker was out of service for 12 months.

CARSON, CALIFORNIA, US | 04/23/2001

217M / 120M

A piping leak resulted in a fire in this refinery coker unit. Smoke rose to over 3,000 feet, and the coker was shut down for about two months.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
215M	90M

RICHMOND, CALIFORNIA, US | 04/10/1989

A two-inch diameter line carrying hydrogen gas at 3,000 psi failed at a weld, resulting in a high-pressure hydrogen fire. The fire resulted in flame impingement on the calcium silicate insulation of the skirt for a 100-feet-high reactor in a hydrocracker unit. The reactor's steel skirt, which was between 10 and 12 feet in diameter and had a wall thickness of 7 inches, subsequently failed. The falling reactor damaged air coolers and other process equipment, greatly increasing the size of the loss.

At the time of the loss, the Hydrocracker unit was being shut down for maintenance and the reactor was in a hydrogen purge cycle. The initial hydrogen leak is believed to have resulted from the failure of an elbow to reducer weld in the two inch diameter hydrogen preheat exchanger by-pass line.

212M / 100M

RYAZAN, RUSSIA | 08/07/1994

The event occurred on a crude unit at the 360,000 bbl/d refinery. A furnace was under maintenance when a worker performed a hot cut and material was released. Inadequate flushing and blinding, and a work scope that did not meet normal industry practices, appear the likely causes.

205M / 75M

FORT MCMURRAY, ALBERTA, CANADA | 08/15/1984

Erosion failure in a 10-inch diameter slurry recycle oil line, in an 82,000 bbl/d fluid bed coking unit, released liquids close to their auto-ignition temperature. A vapor cloud covering a large area ignited almost immediately, resulting in a ground fire covering a large area that led to the failure of six or seven additional lines. The fire eventually extended over a 150-feet diameter area, with damage in the unit structure up to a height of more than 100 feet.

Metallurgical examination revealed that a 1.8-inch-long piece of carbon steel pipe had inadvertently been inserted into the slurry recycle line, made of 5% chrome, during an earlier metals inspection.

The reactor fractionator, light gas-oil stripper, 15,000hp air blower, pumps, and pipe racks were severely damaged or destroyed.

About 2,700 barrels of hydrocarbon liquids were released from process equipment during the fire. Much of this was by gravity flow from ruptured lines although pumps, which could not be shut down, contributed much of the flow. A 900 psig steam line that supplied the turbine drivers of the compressors, ruptured, hampering fire-fighting efforts.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

204M / 143M

MAZEIKIU, LITHUANIA | 10/12/2006

The fire on the vacuum distillation unit (VDU) weakened the main vacuum distillation column supports, allowing it to collapse onto the heat exchange train. The VDU was shut down completely, and the refinery was left running at a much reduced capacity. An investigation found the fire was caused by a leak from a branch on the column, which was fabricated from incorrect material.

191M / 150M

PRIOLO GARGALLO, SICILY, ITALY | 10/13/2008

An explosion and fire in a 562MW-capacity integrated gasification combined cycle electricity generating plant at a refinery caused a fire in the gasification unit. No one was injured by the explosion and fire, but the loss resulted in the refinery's temporary closure.

187M / 150M

SOHAR, OMAN | 03/11/2013

The refinery suffered a fire in a wet-gas scrubber while conducting a planned shutdown and maintenance of the plant equipment, including the polypropylene plant. Personnel were evacuated from the site and there were no injuries.

176M / 150M

PULAU BUKOM, SINGAPORE | 09/28/2011

A fire broke out on the refinery, reportedly started in a pump-house used for blending refined products as it was being prepared for maintenance. Site fire fighters were supported by state fire authority forces. Non-essential staff were evacuated from the site and neighboring units were shut down as a precaution. Further fire eruptions and explosions were reported the next morning. The company commenced steps to shut down the whole refinery. The fire was reported as extinguished late in the evening of the second day — about 34 hours after the fire was first reported. The refinery's production units were progressively restarted, with all units back in production by the end of 2011.

Manufacturing site on Pulau Bukom Island.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
175M	175M

ABIDJAN, IVORY COAST | 01/03/2017

A hydrogen leak on a reactor ignited causing a fire in the hydrocracking distillation unit 87, causing extensive damage to the main reactor. No fatalities were declared.

175M / 78M

WILMINGTON, LOS ANGELES, CALIFORNIA, US | 10/08/1992

An explosion originating in the hydrogen processing unit occurred in the 75,000 bbl/d refinery. The explosion and subsequent fires caused extensive damage to the hydrocracker, hydrodesulphurisation, and hydrogen processing units. The fires were fueled by hydrocarbons released from the damaged process column and equipment. The explosion damaged nearby buildings and shattered windows several miles away. It was recorded as a "sonic boom" at the California Institute of Technology in Pasadena, approximately 20 miles from the refinery.

The explosion resulted from the rupture of the outside radius of a six-inch diameter carbon-steel 90° elbow, and the release of a hydrocarbon-hydrogen mixture to the atmosphere. The vapor cloud ignited within seconds of the rupture. There were no out-of-range or warning indications, until after the failure of the pipe elbow. An inspection afterwards found the line at nearly full design thickness a short distance away the failure; on these facts, it was concluded that the line failure was the result of the thinning of the carbon steel elbow due to long term erosion/corrosion.

The fire-fighting effort was coordinated by the refinery emergency response team, with the Los Angeles City and Los Angeles County fire departments using the joint incident command system. The refinery emergency response team placed booms in the Dominguez Channel storm drain, to stop oily water run-off generated by the fire-fighting effort from reaching the Los Angeles Harbour. The fire was finally extinguished after three days.

The refinery's gasoline production was reduced to 35,000 bbl/d (approximately 70% of rated capacity), until repairs to the damaged process units were completed.

*Based on December 31, 2019, values.

Petrochemicals

There has been a fairly infrequent occurrence of losses in the sector since the early 2000s.

Fire & Explosion

Explosion

Fire

Mechanical Failure

Natural Catastrophe

Property damage losses at petrochemical plants account for 26% of the 100LL. The major explosion at the fertilizer and pesticides plant at the Chenjiagang Chemical Industry Park in China, in 2019, is the largest petrochemical property damage loss since Pasadena 1989.

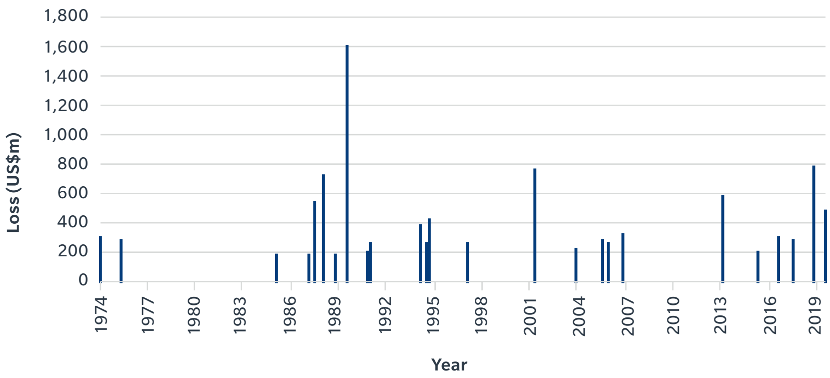
There are no significant trends identifiable, and there has been a steady, fairly infrequent occurrence of losses in the sector since the early 2000s.

That said, a number of factors contribute to petrochemical plants loss history. They often contain a concentration of high-value equipment and machinery, typically operate at high temperatures and pressures, and require the careful control of violent chemical reactions. On the other hand, materials processed at petrochemical plants have normally been pre-processed (for example, supplied by oil refineries), meaning that most contaminants in the feedstocks will have been removed prior to receipt, making them less susceptible to several corrosion mechanisms.

FIGURE 20

Pasadena in 1989 remains by far the largest petrochemical property damage loss.

SOURCE: MARSH



ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

1,615M / 675M

PASADENA, TEXAS, US | 10/23/1989

A large flow of ethylene and isobutane was released from one of the high density polyethylene (HDPE) units at a chemical complex. The vapor cloud drifted north toward the center of the HDPE process area before ignition. This is believed to have occurred approximately 60 seconds after the release. The explosion had the strength of a 3.5 magnitude (Richter scale) earthquake.

The explosion destroyed two HDPE units, which included a total of eight particle form, loop reactor trains. The explosion's heat caused boiling liquid expanding vapor explosions of nearby pressurized storage tanks. Other process units at the chemical complex sustained only minor damage and resumed normal production within a few weeks.

The initial release of ethylene and isobutane occurred through an eight-inch diameter ball valve a settling leg of one of the loop reactors. The function of these pneumatic valves is to isolate the settling leg and other downstream equipment from the reactor for maintenance. The company maintenance procedures for opening a settling leg included closing the ball valve, inserting a lock-out device into this closed valve, closing the block valves to the air hoses for the valve operator, and disconnecting these air hoses.

Company personnel confirmed that these maintenance procedures were performed two days before the loss, but maintenance work had not commenced due to changes in priorities. The work on the settling leg was started on Monday, October 23.

After the explosion, investigations indicated that the lock-out device had been removed from the valve and the air hoses had been reconnected to the valve operator on settling leg. The valve was found in the open position and the settling leg was open to atmosphere at the bottom of the leg, where a swedge/reducer spool leading to the product take-off valve should have been connected.

800M / 800M

CHENJIAGANG CHEMICAL INDUSTRY PARK, CHINA | 03/21/2019

A major explosion occurred at the chemical plant, which is located within an industrial park area and understood to produce fertilizers and pesticides.

The force of the blast started numerous fires in the local town and knocked down several buildings. Considerable damage was caused to nearby factories and offices; the roof of another chemical factory, around 3km from the explosion, reportedly fell in. Windows were reportedly blown out up to 6km away from the explosion, and houses and other buildings were damaged in the nearby village-level administrative divisions. It is understood the explosion was strong enough that it registered on earthquake sensors and could be seen by satellites. The blast created a crater resulting in a magnitude 2.2 seismic shock, with over 900 firefighters required to get the fire under control.

It is understood that nearly 80 people were killed and around 640 people injured as a result of the incident.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

779M / 430M

TOULOUSE, FRANCE | 09/21/2001

A large explosion occurred in an ammonium nitrate storage warehouse of a fertilizer plant, just outside Toulouse, which contained approximately 300 tons of off-specification ammonium nitrate crystals. The explosion had the strength of a 3.2 magnitude (Richter Scale) earthquake, left most of the plant in ruins and damaged surrounding areas. Thirty people were killed in the blast and approximately 3,000 people were injured.

737M / 300M

HENDERSON, NEVADA, US | 05/04/1988

An explosion at a plant that manufactured ammonium perchlorate (AP) for rocket fuel flattened the local industrial park, left a crater 125 meters across, and cracked walls 15 miles away. Two people were killed. The cause is thought to be a fire in a batch dryer. The initial explosion was equivalent to 108 ton of TNT, with a second explosion four minutes later equivalent to 235 ton of TNT. Approximately half 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.

549M / 215M

PAMPA, TEXAS, US | 11/14/1987

An explosion occurred in an air-line in a reactor, used for the liquid phase oxidation of butane, as it was being started. The explosion ruptured the external portion of the air-line to the reactor, allowing the reactor's contents to vaporize and form a cloud. The vapor cloud drifted and ignited about 25 to 30 seconds after the initial release. The vapor cloud explosion caused extensive property damage in the immediate area, and significant damage throughout the site. Windows were broken seven miles away. The immediate cause was believed to be insufficient purging of the reactor when it had previously been down.

500M / 500M

HOUSTON, TEXAS, US | 11/27/2019

An explosion occurred that shattered windows and ripped doors of nearby homes. A second blast followed 13 hours later, and it took several days to extinguish the resulting fires. Three out of the 30 workers on site at the time of the initial explosion were injured.

Around 60,000 people within a four-mile radius of the chemical plant were asked to evacuate due to concerns over air quality. Elevated levels of butadiene were registered as well as other volatile organic compounds, exposure to which can cause irritation, shortness of breath, headaches, and nausea.

The explosion's cause has not been determined yet, but is said to have occurred in the south processing unit at a tank with finished butadiene.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

430M / 203M

PORT NEAL, IOWA, US | 12/13/1994

An explosion occurred in the plant's ammonium nitrate process area. As a result, the seven-story main process building was destroyed and a 30-foot diameter crater was created.

Metal fragments from the explosion punctured one of the plant's two 15,000 ton refrigerated ammonia storage tanks. The punctured tank released an estimated 5,700 tons of ammonia, causing the evacuation of approximately 2,500 people from the surrounding area. Metal fragments also punctured a nitric acid tank, resulting in the release of approximately 100 tons of this acid. The explosion tore metal siding from adjacent buildings, damaged three third-party electric generating stations, broke windows of buildings 16 miles away in Sioux City and was felt more than 30 miles away.

BELPRE, OHIO, US | 05/27/1994

386M / 182M

An abnormal chemical reaction occurred during the batch production of a thermoplastic rubber product, resulting in an explosion. The reactor, process controls, accessories, control room, and building for this production unit were completely destroyed as a result.

The fire spread to involve part of the tank farm, resulting in the destruction of five atmospheric storage tanks. Around midday the first of four 1,000,000-US-gallon and one 500,000-US-gallon styrene storage tanks exploded. A fire-fighting attack using cooling water and foam hose streams was used to prevent the fire from involving other nearby storage tanks, two of which contained butadiene. The fire was extinguished after approximately nine hours.

NIIGATA, JAPAN | 03/20/2007

326M / 240M

An accident occurred at a methylcellulose manufacturing facility. An explosion occurred, followed by a fire, which was extinguished about seven hours later.

Seventeen people working at the site were injured; three critically, five seriously, and nine with minor injuries. There was one minor injury off site. Ignition of the methylcellulose powder is thought to have been due to static electricity, resulting in a powder dust explosion. All methylcellulose operations were suspended for two months before sequentially restarting.

PORI, FINLAND | 01/11/2017

325M / 325M

A fire occurred at a titanium dioxide manufacturing facility, resulting in significant damage to the plant and the halting of production of the pigment. It is understood that a fire in the electrostatic precipitator quickly spread to the pipe network and manufacturing halls.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
315M	58M

FLIXBOROUGH, UK | 06/01/1974

The chemical facility was severely damaged by a large vapor cloud explosion. Twenty eight workers were killed, and a further 36 suffered injuries. The number of fatalities would have been higher had it not been a weekend, as the main office block was not occupied. Offsite consequences resulted in 53 reported injuries. Properties in the surrounding area were damaged to varying degrees. Before the loss, a reactor had been removed and a bypass assembly installed to enable production to continue. On June 1, the 20-inch bypass system ruptured, possibly caused by a fire on a nearby eight-inch pipe. This resulted in the release of 30 tons of hot cyclohexane, which formed a flammable cloud that found a source of ignition. Eighteen fatalities occurred in the control room as a result of windows shattering and the roof collapsing. Ensuing fires burnt for more than three days.

298M / 60M

ANTWERP, BELGIUM | 10/02/1975

An explosion and fire caused extensive damage at a low-density polyethylene plant. The cause was a leak of ethylene at high pressure, due to fatigue failure of a vent connection on the suction of a compressor. Six people were killed, and 13 injured.

298M / 200M

MUNCHMUSTER, GERMANY | 12/10/2005

A release of hexane created a vapor cloud that was ignited on an electric motor, causing an explosion. This resulted in damage to a process unit and 20 injuries. The plant was eventually replaced.

290M / 290M

LUDWIGSHAFEN, GERMANY | 10/17/2017

Maintenance work was taking place on a transfer line between the plant's processing areas and a jetty facility located on the river nearby, relatively near the jetty. It is understood that at some point during the maintenance work, a cut was made in a line that was live, instead of the planned line. This led to a release of hydrocarbon, causing a gas cloud to form. The cloud ignited, leading to an explosion and fire, which led to releases from at least one other pipeline nearby. It is understood that both ethylene and propylene were released as a result of the incident.

The fire following the explosion took around 10 hours to extinguish. Residents of the local town and a nearby city were told to remain inside for at least 24 hours following the incident. Most the site's different process units were shut down immediately following the incident as a precaution. Five people were killed in the incident, understood to include two plant operators, two fire fighters from the site, and a crew member of a ship docked at the jetty area. At least 10 other people were injured.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

PORT ARTHUR, TEXAS, US | 04/29/2006

285M / 200M

A shelter-in-place was ordered 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.

CEDAR BAYOU, TEXAS, US | 10/20/1994

276M / 130M

The Texas floods along the San Jacinto river shut down the site, involving 650,000 t/y ethylene; 200,000 t/y LLDPE; 280,000 t/y LDPE plants; and general utilities. The loss of utilities affected downstream clients. Flood water breached dikes around the main substation and inundated control rooms and offices.

STERLINGTON, LOUISIANA, US | 05/01/1991

274M / 120M

Workers were preparing to check a compressor in the Nitroparaffin unit when they noticed a small fire and sounded the plant's fire alarm. Approximately 30 seconds later, an explosion occurred that was followed by a series of smaller explosions. The initial explosion's effects were reported as far as eight miles away. It completely damaged an area of the plant about the size of a city block. Subsequent fires were reported to have burned for more than seven hours.

Although the incident did not damage the two ammonia units on-site, the entire plant was temporarily shut down for precautionary measures.

DEER PARK, TEXAS, US | 06/22/1997

267M / 135M

An explosion and large fire occurred at a petrochemical plant. The explosion was felt and heard over 10 miles away, and the ensuing fire burned for approximately ten hours. The explosion and fire resulted in extensive damage to the facility, and several workers received minor injuries. Nearby property was damaged, nearby transport routes were closed for several hours, and residents were advised to remain indoors. The incident originated at the cracked gas compressor system in the Olefins unit and was caused by the structural failure of a 36-inch pneumatically-assisted, non-return valve located on a high-pressure light hydrocarbon gas line. The escaping gas formed a vapor cloud and eventually found a source of ignition, resulting in the unconfined vapor cloud explosion.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
234M	150M

ILLIOPOLIS, ILLINOIS, US | 04/23/2004

Five people were killed and two seriously injured following an explosion at a plastics plant producing 200 million barrels per year of speciality grade PVC. The explosion was felt eight kilometers away. The highway was shut and local residents evacuated. The explosion occurred in a reactor where vinyl chloride and vinyl acetate were being mixed. Up to 75% of the plant was destroyed in the explosion.

221M / 97M

PAJARITOS, COATZACOALCOS, MEXICO | 03/11/1991

A gas leak involving the pipe rack that runs to the terminal in the petrochemical complex led to an explosion. An initial explosion occurred near the complex chemical plant, causing additional damage to the pipe rack and resulting in a major gas leak. A powerful second explosion occurred that could be felt more than 15 miles from the complex. This explosion and the subsequent fire completely destroyed the chemical plant, caused significant damage to the pipe rack, and also caused moderate damage to other complex buildings and adjacent third-party facilities. The fire was extinguished after approximately three hours.

Because of the incident, the chemical plant at this complex was completely shut down for seven months, to allow for the rebuild of the plant and pipe rack.

206M / 90M

SEADRIFT, TEXAS, US | 03/12/1991

An explosion occurred in the plant's ethylene oxide process unit. As a result of the explosion, the ethylene oxide refining column was completely destroyed, the ethylene glycol unit was substantially damaged, and the co-generation unit was partially damaged. A pipe rack near the storage area for liquid ethylene oxide was damaged when a large piece of shrapnel from the explosion hit the rack, rupturing lines that contained methane and other hydrocarbon products. The fire that resulted from the released products was the only significant one to occur during the incident.

As a result of the explosion, all utilities at the plant were lost for about a week. Additionally, a significant number of fixed-fire protection systems were damaged by the explosion or inadvertently actuated due to a loss of plant air. These systems were shut off and isolated, or placed back in service, as appropriate. A manual fire-fighting effort was used to extinguish the fire in the pipe rack once the lines in the rack were isolated.

The polyethylene production was restarted in early April 1991, using imported ethylene. The olefins production unit was restarted in late April 1991.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
199M	78M

ZWIJNDRECHT, ANTWERP, BELGIUM | 07/03/1987

An explosion occurred in the final purification column of an ethylene oxide manufacturing plant, resulting in 14 people being injured. The explosion initiated several secondary fires on the original units and other units nearby, but all were under control within 30 minutes. The root cause was a rapid over-pressurization of the column as a result of decomposition of material within it, although the ignition source was not identified.

197M / 74M

PRIOLO, ITALY | 05/19/1985

A faulty temperature probe on a 600,000-ton-per-year ethylene plant initiated an isolation of the hydrogenation reactor located within the cold section. While the operators were attempting to regain normal control, the pressure relief system operated. About the same time, fire was noted near grade level at the base of the deethaniser column. The source of fuel was believed to have been a flange at the deethaniser column reboiler or in the relief system pipe work.

Leaking hydrocarbon, mostly propylene at 375 psig, was possibly ignited by hot steam piping. The intense fire rapidly engulfed the adjoining ethylene and propylene distillation columns and spread 180 feet to the storage area. Eventually one vertical pressurized propane storage tank exploded, its top section travelling 1,500 feet and missing a gas holder by 30 feet. Two other propylene tanks toppled; one onto a pipe rack and the other against an ethylene tank. All were protected by deluge waterspray systems that were said to be ineffective under the intense fire exposure. Five of the eight ethylene and propylene tanks collapsed or exploded. The fire also spread to the API separator and to three floating roof tanks. Pipe racks, motor control centers, and pumps were severely damaged or destroyed.

Minutes after the fire brigade responded, the ethylene column released its 9,300-US-gallon inventory, destroying one of the plant's two foam trucks. Assisted by outside fire-fighting agencies, the plant's fire brigade brought the fire under control over 40 hours and extinguished it four days after the initial ignition.

191M / 80M

UERDINGEN, GERMANY | 02/14/1989

A runaway reaction triggered an explosion and fire, which destroyed the plant and a neighboring building. The wrong components were added to chemical mixture.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)* | ACTUAL PROPERTY DAMAGE LOSS (US$)

190M / 79M

ANTWERP, BELGIUM | 03/07/1989

A hairline crack in a welded seam of piping to the level indicator system on an aldehyde column, resulted in a minor ethylene oxide leak on the gas processing plant. The crack was caused by low cycle fatigue, and led to ethylene oxide escaping near the level indicator and forming polyethylene glycols (PEG) in the mineral wool insulation.

It is believed that both the leak and accumulation of PEG occurred over a period of time. During repairs to the level indicator, the metal sheathing of the insulation was removed and air contacted the insulation soaked with PEG. Auto-oxidation of the PEG resulted and the insulating material was ignited. The piping to the level indicator system was heated to such a degree that auto-decomposition of the ethylene oxide within the piping occurred. This auto-decomposition propagated into the aldehyde column, which subsequently exploded.

The force of the explosion destroyed the distillation section of the plant. The large resulting fire, and debris flying to other process sections, caused extensive damage throughout the plant.

175M** / 155M**

LITVINOV, CZECH REPUBLIC | 08/13/2015

A short interruption in the supply of cooling water to a separation column, downstream of a steam cracker, resulted in the need to open relief valves from the column to flare. Subsequent manual choking back of the relief line to flare resulted in the pressure relief valves opening. These valves vibrated excessively, resulting in the failure of the bolted flanges and release of the propylene-rich column overhead line into the atmosphere. The resultant explosion led to the failure of utility lines to the cracker requiring a crash shutdown. The lack of process steam due to the interruption to the utility supply resulted in the failure of furnace tubes and the release of quench oil. There was subsequently a pool fire from the released quench oil under the cracker, resulting in damage to four of the ten cracker furnaces.

*Based on December 31, 2019, values.

**Loss estimate based on a settlement reached in 2019.


安全 優先

Gas Processing

Excellent global experience with the design, construction, and operation of LNG facilities results in relatively few very large losses.

Fire & Explosion

Explosion

Natural Catastrophe

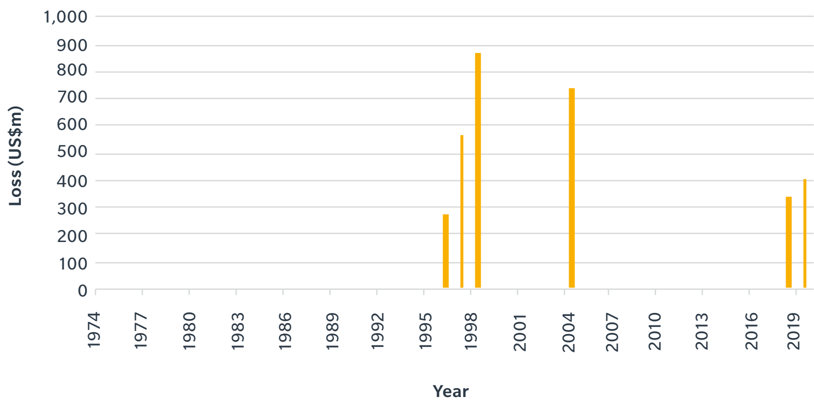
Six property damage losses associated with gas processing feature among the 100LL — two of which occurred in the past two years.

The properties of LNG mean that the risk of internal corrosion is virtually eliminated. And excellent global experience with the design, construction, and operation of LNG facilities results in relatively few very large losses. The potential remains, however, for high-consequence losses at facilities of this type due to their complexity and value — as underlined by the property damage caused by both the recent fire/explosion at the facility in Arzew, Algeria, and the earthquake in Papua New Guinea.

FIGURE 21

In 2018-19 two gas processing losses entered the 100LL.

SOURCE: MARSH



ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
865M	443M
736M	470M
563M	285M

LONGFORD, VICTORIA, AUSTRALIA | 09/25/1998

Gas supplies to Australia's Victoria State were virtually shut down following an explosion and fire at this gas processing plant. The cause of the accident was attributed to the rupture of a heat exchanger following a process upset that was set in motion by the unintended, sudden shutdown of hot oil pumps. The loss of hot oil supply resulted in some vessels being chilled by cold oil. When the hot oil was reintroduced to a heat exchanger the vessel ruptured due to a brittle fracture. An initial release of approximately 22,000lb of hydrocarbon vapor exploded, and an estimated 26,000lb burned as a jet fire. The fire burned for two and 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 plant upset with tragic loss of life.

SKIKDA, ALGERIA | 01/19/2004

Twenty seven people were killed, seventy two injured and seven reported missing following an explosion at this LNG plant. The explosion destroyed three out of six liquefaction trains, damaged a nearby power plant and led to the shutdown of a 335,000 bbl/d refinery. There was also some damage to the neighbouring industrial facilities. A faulty boiler was initially blamed for the incident. Investigations however indicated that a large release of hydrocarbon from a cold-box exchanger was ignited upon ingestion into the boiler. Train 6 of the LNG Complex re-started in May 2004 and Trains 5 and 10 in September 2004. Trains 20, 30 and 40 were destroyed in the incident representing 50% of the capacity of the LNG complex.

BINTULU, SARAWAK, MALAYSIA | 12/25/1997

An explosion and fire occurred at a gas-to-liquids (GTL) plant, with the fire brought under control the next day. The plant was one of only two commercially successful GTL plants in the world at the time, with a capacity to produce 12,500 bbl/d of middle distillates and waxes from natural gas feedstocks. The explosion occurred in the air separation unit (ASU), which supplied oxygen for the production of synthesis gas feedstock.

The investigation into the incident pointed to an initial combustion event in the ASU as the most probable cause. This combustion event is thought to have initiated explosive burning of the aluminum heat exchanger elements in the presence of liquid oxygen, such that the elements ruptured explosively. Twelve people were injured, none seriously, and the plant was shut down for several months for repairs.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
400M	400M**

ARZEW, ALGERIA | 07/01/2019

A fire broke out at Algeria's main liquefied natural gas (LNG) complex in Arzew's petrochemical hub. The fire was preceded by two explosions that were reported to shake industrial and residential buildings kilometers away. Many people initially took the blasts for an earthquake, because of their intensity. Four people were reportedly injured in the incident.

335M / 335M

KOMO, PAPUA NEW GUINEA | 02/26/2018

The earthquake struck with an intensity of M7.5 (MM IX), with aftershocks over the following weeks. The event caused building and infrastructure damage, and sinkholes and landslides. Over 160 people were killed from the local communities and many injured. The damage affected the local airport at Komo, which was significantly damaged, the gas conditioning plant — which was safely shut down with some damage but no loss of containment — and the 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 quote here is believed to be the reserve across all elements of the loss — airport, gas plant, and pipeline.)

276M / 137M

CACTUS, REFORMA, CHIAPAS, MEXICO | 07/26/1996

A vapor cloud explosion centered in the Cryogenic Unit No.2 and two subsequent explosions in the Cryogenic Unit No.1 occurred at this gas processing complex. The Cryogenic Unit No.2 and LPG product pumps in the Cryogenic Unit No.1 were extensively damaged, the control rooms for both units were destroyed, and the remainder of the Cryogenic Unit No.1 experienced minor damage.

Plant personnel noticed that one of the two LPG product pumps in the Cryogenic Unit No.1 had a seal leak, and decided to have the faulty seal replaced. In preparation for the maintenance work on the LPG product pump, the motor operated valve (MOV) in the suction line and the isolation valve in the discharge line of the pump were manually closed. A spectacle blind was then inserted into the pump flange on the suction side of the pump. After the seal was replaced, plant personnel removed the blind and were in the process of tightening the flange bolts when LPG product began to leak from this flange. A vapor cloud formed and drifted into the Cryogenic Unit No.2. It ignited and resulted in the initial explosion. Following the explosions, it was determined that the MOV in the suction line of the pump was in the open position, which allowed the LPG product to reach the pump flange.

The fire brigades successfully extinguished the fire following the explosions after approximately three hours, and protected the adjacent LPG spheres. Although the explosions damaged the electric power in the plant and rendered the electric motor-driven fire water pumps non-operational, fire water was provided by two diesel engine driven fire water pumps.

Because of this incident, the 2.13 billion ft3/y gas processing capacity at this complex was shut down, disrupting a third of Mexico's total gas processing capacity.

* Based on December 31, 2019, values.

**Loss value may reduce from initial estimate as further information becomes available.

Terminals & Distribution

Few sites have enough concentration of value to result in the very largest property damage accidents.

- Fire & Explosion
- Explosion
- Fire
- Mechanical Failure
- Natural Catastrophe

Only five losses associated with terminal and distribution operations feature among the 100LL — the most recent occurring in 2002.

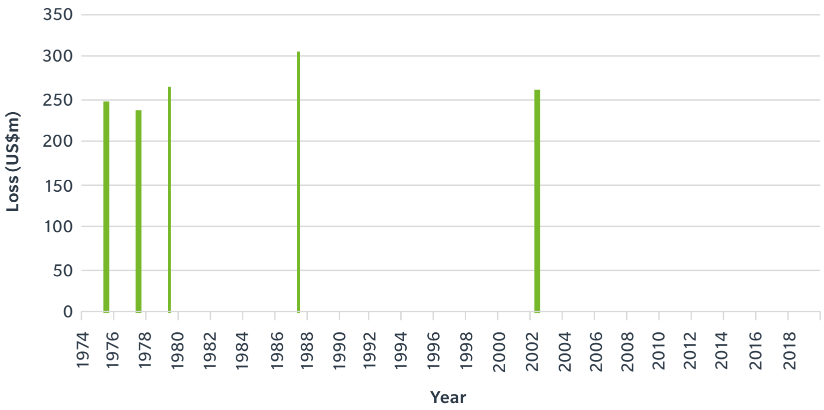
The physical layout of most terminals and distribution assets, coupled with the value of the plant and its equipment, means that few sites have enough concentration of value to result in the very largest property damage accidents if the worst were to occur.

Of special note is the fire at the ITC tank farm in the US in March 2019. A leak of naphtha ignited and led to a full-surface tank fire at the facility. This then spread to other tanks (the typical tank-to-tank separation was approximately 0.4 tank diameters), resulting in the destruction of at least 12 of the 15 tanks onsite. The property damage of roughly US$125 million, however, was insufficient to include it in the 100LL.

FIGURE 22

Terminals and distribution losses have not featured in the 100LL since 2002.

SOURCE: MARSH



ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

306M / 120M

ANDES, ECUADOR | 03/05/1987

Twenty-five miles of Trans-Andean pipeline disappeared in the event, which also damaged natural gas and gasoline pipelines. All 285 producing wells were shut down, and oil exports were suspended and swap arrangement made with Venezuelan suppliers. The first earthquake registered 6.0 on the Richter scale, the second 6.8, and there were ten earthquakes in total. Repairs took several months.

265M / 70M

BANTRY BAY, IRELAND | 01/08/1979

An 11-year-old 121,000-deadweight-tons tanker had unloaded its first parcel of Arabian heavy crude at a deep-water port. No transfer operations between the ship and the jetty were in process when a small fire was noticed on deck. About 10 minutes later fire spread along the ship and was observed on the sea at both sides of the ship. After 30 minutes, a huge explosion occurred. It is theorized that the disaster was initiated by the buckling of the ship's structure at, or around, deck level. This was immediately followed by explosions in the ballast tanks and the breaking of the ship's back. These events were produced by the conjunction of two separate factors: 1) a seriously weakened hull due to inadequate maintenance, and 2) excessive stress due to incorrect ballasting at the time of the disaster.

A fragment of the ship weighing 1,000lb was found at the base of a large crude oil tank, 1,800 feet from the ship. In addition to the total loss of the ship, 50 people lost their lives, and 1,130 feet of the concrete and steel jetty were damaged or destroyed.

261M / 150M

RAUDHATAIN, KUWAIT | 01/31/2002

Four people were killed in an explosion and fire at the oil gathering center, gas booster station, and power substation. The explosion occurred after a leak from a buried oil pipeline in the gathering station spread to a power substation, sparking the blaze. The flash explosion and resulting blaze hit the gathering center and adjacent gas booster station. Nineteen people were injured in the incident, suffering mainly first- and second-degree burns. The fire was extinguished two days after the event.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

249M / 50M

MARCUS HOOK, PENNSYLVANIA, US | 01/31/1975

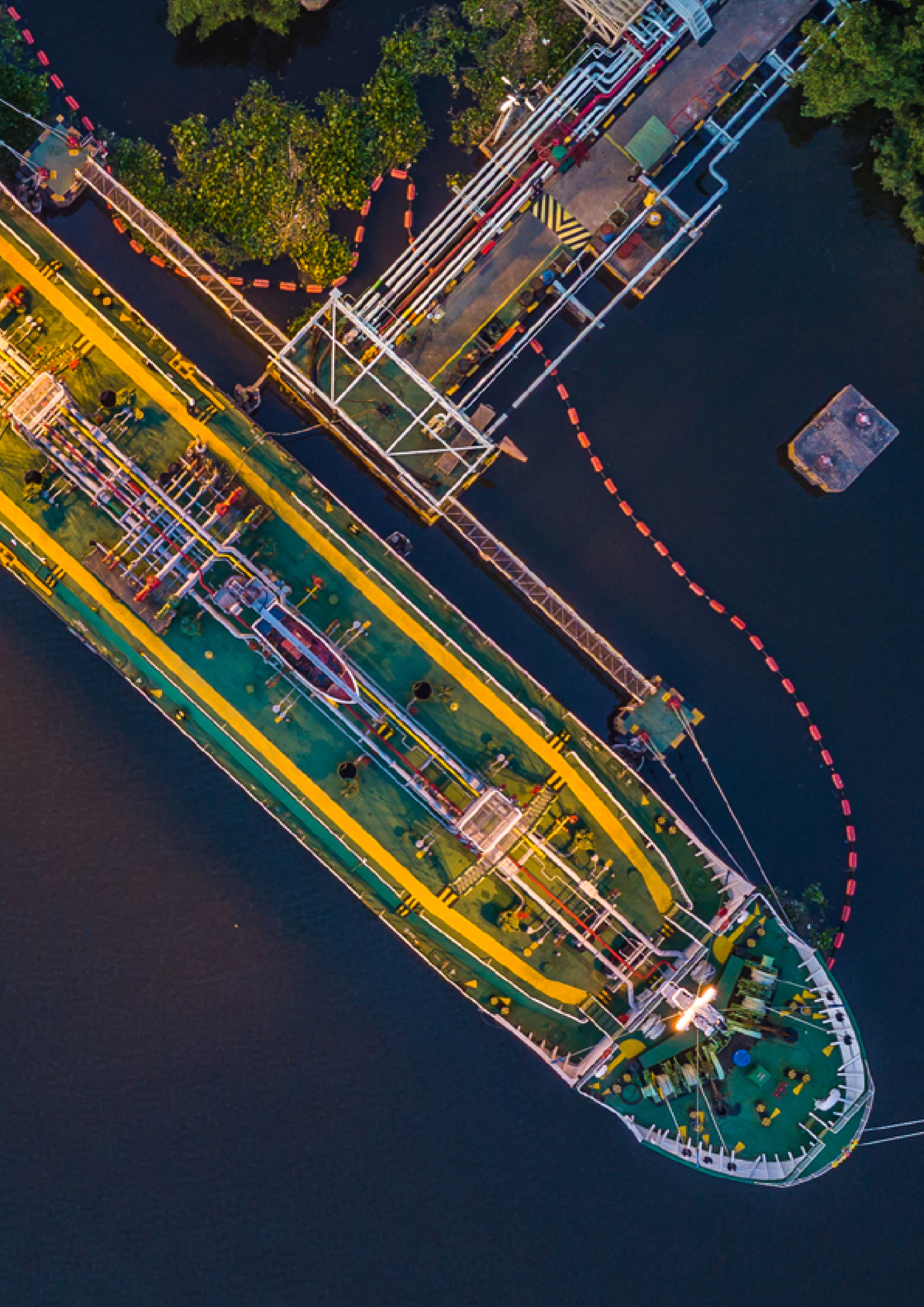
The United States flag tanker “Edgar M. Queeny” rammed the Greek tanker “Corinthos,” while the latter was discharging 400,000 bbl of crude oil at a refinery jetty at Marcus Hook on the Delaware River. A huge initial explosion, and subsequent explosions and fires, occurred on the Greek ship as a result. Twenty-five crew members were killed on board the vessel, in addition to a crewman from the flag tanker. The Corinthos sank shortly afterwards and was later removed for scrapping.

239M / 55M

ABQAIQ, SAUDI ARABIA | 05/11/1977

A 30-inch diameter crude oil pipeline failed and destroyed three spheroids, pumping units, and other equipment. Ignition was caused by motor vehicles.

*Based on December 31, 2019, values.



The Piper Alpha loss in 1988 remains the largest recorded property damage loss.

Fire & Explosion

Explosion

Fire

Mechanical Failure

Hurricane/Storm

Blowout

Collision

Upstream

Since 2016 there have been no additions to the 100LL from the upstream sector, which accounts for 24% of the 100LL. The Piper Alpha loss in 1988 remains the largest recorded property damage loss.

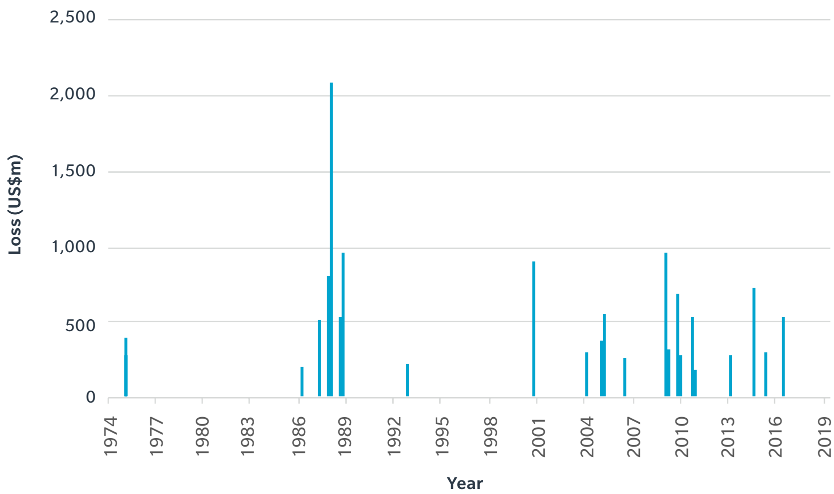
This report only covers property damage and does not include the additional costs of well control or third-party liability (total third-party liability claims for the Macondo loss in the Gulf of Mexico, in 2010, were more than 20 times the value of the associated property damage loss).

The evolution of the upstream industry with increased fracking has continued. These assets are generally of relatively small size and well dispersed, so individual losses associated with fracking have not yet been sufficiently large to feature in the 100LL.

FIGURE 23

The Piper Alpha loss in 1988 remains by far the largest upstream property damage loss.

SOURCE: MARSH



ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

PIPER ALPHA, NORTH SEA, UK | 07/06/1988

2,088M / 850M

A release and ignition of gas condensate from a section of piping in the gas compression module of the platform set off a chain of fires and explosions, resulting in the facility's almost total destruction. The condensate was released from the site of a pressure-relief valve that had been removed for maintenance, when this section of piping was inadvertently pressurized. The severity of the accident was due largely to the contribution of oil and gas from ruptured pipelines connected to the platform, and the disabling of nearly all emergency systems as a result of the initial explosion. The compression module had been retrofitted to the platform adjacent to the control room, and the control room was rendered useless by the initial explosion.

In addition, the firewater pumps had been placed in manual operation mode due to divers being in the water before the accident.

There were 226 people on the platform at the time of the accident; only 61 survived. Contributing to the loss of life was the location of the quarters directly over the site of the initial release and resulting explosion and fire.

EKOFISK, NORTH SEA, NORWAY | 06/04/2009

967M / 750M

A well-intervention vessel lost power and collided with an unmanned platform forming part of this 230,000 bbl/d complex. Heavy damage was caused to the vessel and platform, including damage to the platform structure, linking access bridge and well equipment. Some 23,000 bbl/d of oil production was reportedly affected. The force of the collision caused the bow of the vessel to compress by about two meters, with the platform pushed partly out of position, loosening several support legs from the main load-bearing structure. One of the water injection risers on the platform was bent extensively and several wellheads were moved, with a catalogue of further damage from the collision also identified.

BAKER, GULF OF MEXICO, US | 03/19/1989

957M / 400M

Contract personnel were installing a pig trap on an 18-inch-diameter export gas pipeline on the platform. As a cold cut was made into the pipeline, hydrocarbons sprayed from the cut and ignited. The explosion and fire burned the main structure and caused subsequent explosions when six other pipelines ruptured due to the intense heat. The accident resulted in the platform's destruction and seven fatalities. Two years were required to replace the platform.

RONCADOR FIELD, CAMPOS BASIN, BRAZIL | 03/15/2001

905M / 500M

The world's largest offshore production facility was rocked by a series of explosions caused by a gas release. The explosions knocked out a support pillar of the semi-submersible platform, allowing seawater to enter the vessel. Workers pumped in nitrogen and compressed air and tried to pump out almost 3,000 tons of seawater to keep the rig afloat, but were unsuccessful. On March 20, the rig sank to the sea floor. Eleven workers were killed.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)

ENCHOVA, CAMPOS BASIN, BRAZIL | 04/24/1988

811M / 330M

During the conversion of one of the platform wells from oil to gas production, a high-pressure gas pocket was encountered that forced the drill pipe out of the well. The blow-out preventer failed to shut in the well and sparks — caused by the drill pipe that was ejected from the well hitting one of the platform legs — ignited the escaping gas. The fire lasted for 31 days. Most of the topside structure was destroyed and the facility was later declared a total loss. Redesign of the production module was completed in 45 days in an effort to shorten loss of production as much as possible. Full production was restored 18 months after the loss.

BAY OF CAMPECHE, MEXICO | 01/04/2015

737M / 640M

A complex of six platforms located in 30 meters of water in the Gulf of Mexico was subject to a major fire. The fire originated on the lower decks of the production platform and resulted in major damage to that platform, radiation and fire damage to an adjacent compression platform, the loss of bridge links and pipelines, and radiation damage to other bridge links. The root-cause investigation required by the government identified corrosion of a small bore pipeline as behind the initial failure.

GULF OF MEXICO, US | 04/21/2010

685M / 560M

A semi-submersible drilling rig working in the Mississippi Canyon block 252, approximately 48 miles off the coast of Louisiana, suffered a major explosion and fire following a well integrity failure. The rig had a crew of 126: 11 people were immediately identified as missing and subsequently confirmed as fatalities, with a further 17 injured. The rig sank within 36 hours of the initial explosion in a water depth of approximately 5,000 ft. The exploration well had reached a depth of 18,360ft (total depth), and was undergoing cementing works, prior to the well control event, with a view to temporarily abandoning the well.

Hydrocarbons continued to flow through the damaged blowout preventer (BOP) for 87 days before a successful static kill was performed. The release caused a spill of national significance and resulted in an unprecedented sub-sea and surface spill control response. The well was declared finally killed five months after the original event by successful interception by a relief well.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
552M	370M
536M	450M
527M	450M
526M	220M

*Based on December 31, 2019, values.

MUMBAI HIGH NORTH FIELD, INDIA | 07/27/2005

552M / 370M

Twenty two people were killed when a fire completely destroyed an oil platform. It is believed that a multi-purpose support vessel, which was evacuating a worker to a medical center, hit the platform's riser, causing an explosion. The vessel also caught fire and sank but two nearby platforms were saved when connecting bridges collapsed. The 150 people on board managed to transfer to a nearby water injection platform, and another 348 people were evacuated from the oil platform. However, the rescue operation was hampered by bad weather. A cantilever jack-up rig, linked by a bridge to the process platform, was also involved in the fire. Seventy three people were evacuated from the rig but during the evacuation an employee died. Six divers in a saturation chamber on the vessel were rescued 36 hours later.

JUBILEE FIELD, GHANA | 11/02/2016

536M / 450M

The main turret bearing on a floating production storage and offloading vessel seized and subsequently failed, resulting in the vessel being unable to weathervane. Production was resumed with a revised operating regime employing tugs to maintain a constant heading. Subsequently, the vessel was converted to employ a permanent spread moored configuration, fixing the heading of the vessel and installing an associated deep-water offloading buoy.

NORTH SEA, UK | 02/04/2011

527M / 450M

Heavy storm conditions in the North Sea caused four of this floating production storage and offloading's (FPSO) 10 anchor chains to break, resulting in the vessel moving off its position. It is estimated that the FPSO was subject to 53 knot winds and nine-meter waves. Normally a complex piping system runs from the wells on the seabed up to the FPSO, but this infrastructure was damaged in the incident.

Following the vessel moving off its position all the wells were immediately shut in. Subsequent surveys showed that no oil had been lost. Seventy-four non-essential crew were evacuated to near-by platforms, and 43 essential crew remained on-board. Two members of crew received minor injuries.

The facility was projected to be producing an average of 18,400 bbl/d of oil before the loss.

TREASURE SAGA, NORTH SEA, NORWAY | 01/20/1989

526M / 220M

A semi-submersible rig had a gas kick at 15,527 feet during an attempt to clear the drill pipe of cement previously pumped in to control the well, and the well then suffered a blow-out. The well was stabilized after 11 months by pumping heavy mud down a relief well. The well was later sealed.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
393M	79M

FATEH L3, DUBAI, UAE | 07/01/1975

The Fateh Field L-3 development well had reached 4,180ft when a "kick" occurred. The kick control effort was terminated and the rig abandoned when gas broke around the 20-inch shoe and bubbled up under the platform. Eight days after the blowout, the gas ignited, and after two weeks the rig and platform disappeared beneath the waters.

373M / 250M

GULF OF MEXICO, US | 07/10/2005

Hurricane Dennis passed through the area where the platform was located, causing it to partially sink. A seawater valve in a ballast tank had been wrongly installed, resulting in excess water in the tanks. The platform had already been evacuated and there was no leakage of oil, fuel, or other hazardous substances.

The loss resulted in the project commencing production three years behind schedule. The company retrieved and rebuilt all the sea-bed production equipment after a series of tests revealed metallurgical failure in components of the field sub-sea systems.

322M / 250M

MONTARA, TIMOR SEA, AUSTRALIA | 08/21/2009

Oil, condensate, and hydrogen sulphide leaked from a wellhead on a platform being serviced by a jack-up rig in the Timor Sea. Sixty nine workers on the rig were evacuated. Oil and gas started to spill after a plug blocking one of the project's 1,200-meter-deep wells came free. The next day a 12km-long and 30-meter-wide spill was reported. Attempts were made to plug the well over the next two months. It was estimated the well leaked 400 bbl/d of oil and gas.

On November 1, it was reported that drillers had successfully intercepted the well and were beginning to put heavy mud into the shaft. However, a fire broke out on the drilling platform as it attempted to plug a deeper leak. The fire was extinguished two days later. A total of 4,140 tons of oil was estimated to have been lost. This incident affected both the platform and the drilling rig.

304M / 250M

CAMARUPIM FIELD, BRAZIL | 11/03/2015

An explosion on a floating production storage and offloading (FPSO) vessel off the coast of Brazil resulted in nine fatalities and multiple injuries. The accident happened as the vessel was anchored in the Atlantic Ocean 120km from the coast of Espirito Santos, Brazil. The FPSO is a converted very large crude oil tanker, designed to produce up to 10 million cubic meters of natural gas. It is understood that a condensate leak during a fluid transfer operation released a cloud of flammable vapor into the engine room, resulting in an explosion in the machinery space. Most fatalities were believed to be part of the emergency response team. The FPSO took on water, but the explosion did not result in a breach of the hull of the vessel.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)* / ACTUAL PROPERTY DAMAGE LOSS (US$)	Location / Date	Description
296M / 190M	TEMSAH, EGYPT | 08/10/2004	A fire broke out during drilling operations at an offshore gas production platform following a well-control incident. The fire on the production platform was initially under control but then spread to a nearby jack-up drilling rig, owned by a major drilling contractor, which suffered major damage and collapsed. All 79 people on board the drilling rig were safely evacuated. The production platform, with 150 persons onboard, had been evacuated before the fire spread. The drilling rig sank and was not salvageable. The platform was damaged beyond repair and its destruction was ordered by the state.
288M / 235M	CARIBBEAN SEA, VENEZUELA | 05/13/2010	A natural gas drilling rig sank in the Caribbean Sea, but all 95 workers were evacuated safely and there was no reported leakage. The sinking was caused by a sudden surge of water entering one of the submarine rafts that the platform legs floated on. Automatic sub-sea safety valves sealed the wells and no leakage of oil occurred.
272M / 55M	AUK FIELD, NORTH SEA, UK | 08/01/1975	Platform was struck by the vessel "Stad Sea."
271M / 235M	ATLANTIC OCEAN, OFF ANGOLA | 07/01/2013	A jack-up sank after the sea bed collapsed under one of the three legs. The rig sank while being positioned for drilling operations in approximately 40 meters of water. One hundred and three workers were on-board the rig when it suddenly tilted, causing the rig to take on water and capsize. One crew member was missing and six others received minor injuries.
264M / 185M	NORTH SEA, NORWAY | 11/05/2006	Offshore gas alarms were triggered on the floating production unit and, upon investigation, it was established that a leak was emanating from one of the production risers. Upon further investigation, five other risers were found to be similarly affected. Remedial work was subsequently carried out.
218M / 100M	LAMA, LAKE MARACAIBO, VENEZUELA | 03/25/1993	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. Eleven fatalities resulted from the incident.

*Based on December 31, 2019, values.

ADJUSTED PROPERTY DAMAGE LOSS (US$)*	ACTUAL PROPERTY DAMAGE LOSS (US$)
197M	75M
187M	160M

SEA OF JAPAN, OFFSHORE JAPAN | 08/26/1986

A semi-submersible barge ran aground near Uslan, Japan, during a typhoon.

GULF OF MEXICO, MEXICO | 04/12/2011

Six hundred and thirty-eight workers were evacuated from the flotel after it began to lean to one side when water entered a pontoon. The flotel was located about 80km offshore Campeche, Mexico. No injuries were reported, although a total loss of the flotel reportedly resulted.

*Based on December 31, 2019, values.

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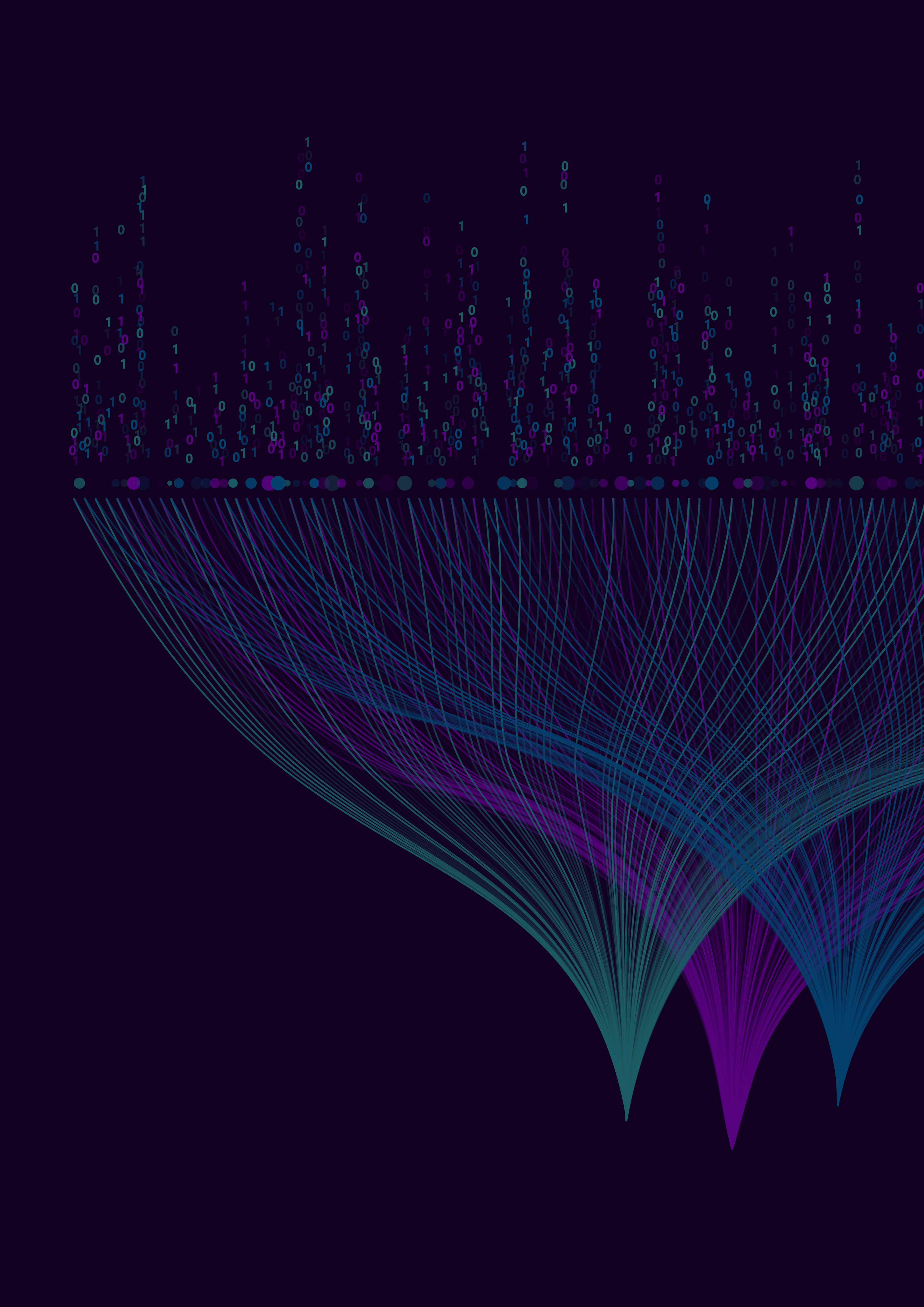

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