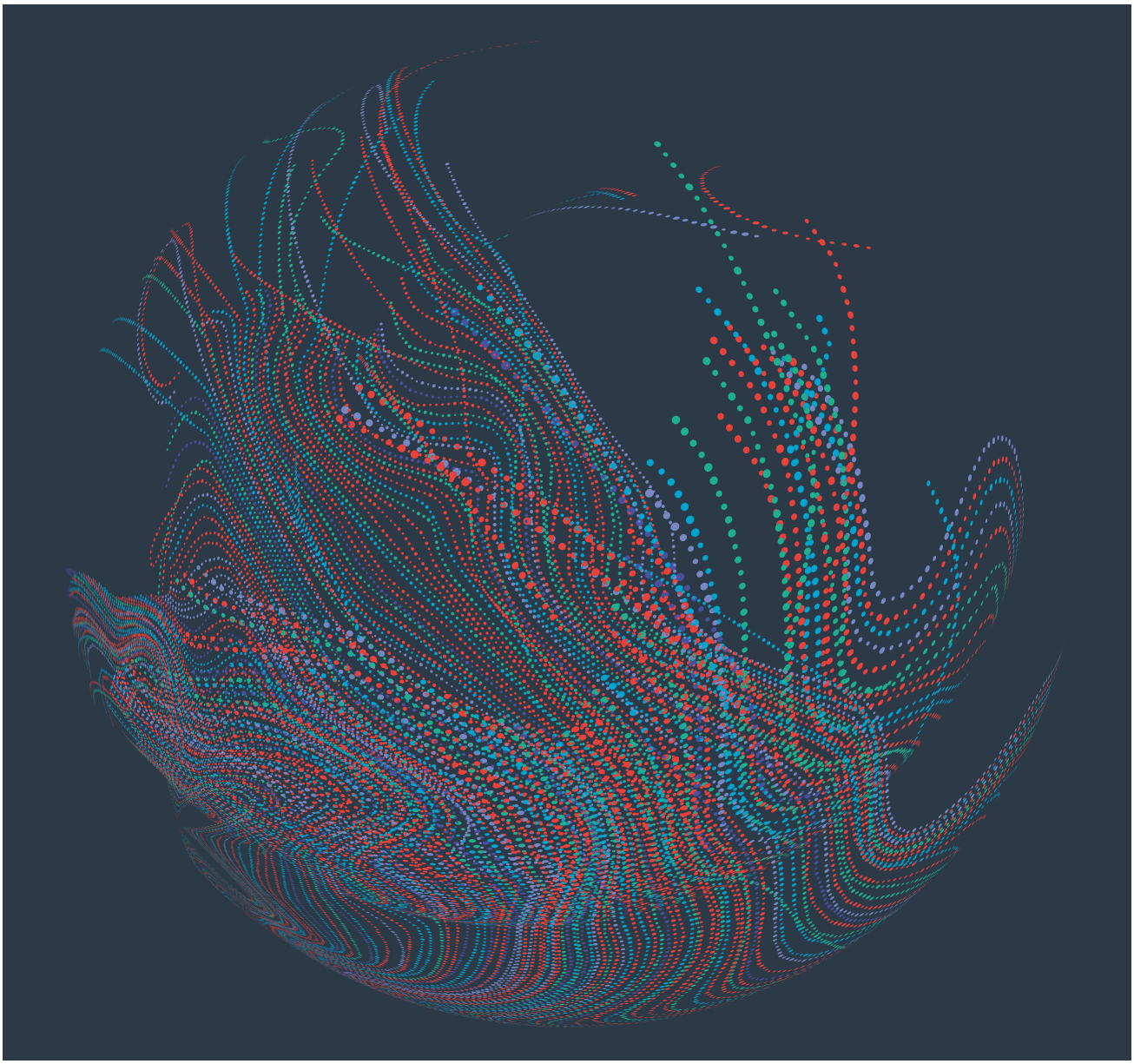
MARSH

The 100 Largest Losses 1978-2017

Large Property Damage Losses in the Hydrocarbon Industry
25th edition



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FOREWORD

Welcome to the 25th edition of Marsh's *100 Largest Losses* report. We hope that the information summarized in this publication proves to be a valuable resource for energy industry professionals.

Given the challenges that face the energy industry today, ranging from adjusting to a prolonged period of low oil prices, to the evolution that new and disruptive technology will bring, considering the potential for serious incidents or major losses has never been more crucial. And in many cases, there are important lessons to be learned from the past.

To help bring this information to the industry, Marsh has been collecting and recording data on major property damage losses in the energy industry since the publication of the first edition of this report, and now has a database with more than 10,000 incidents from across the global industry.

This data can support organizations in their hazard identification activities, highlighting the particular exposures relevant to the technologies they are developing and managing these based on historical loss records. This information should be complimented by that collected and recorded on losses and near misses within organizations to further support improvements in risk management practice.

Many risk improvement recommendations are based on the experience of energy industry insurers, including the experience from the major property damage losses summarized in this publication.

Ian Henderson
Global Energy & Power Engineering Leader

HARNESSING THE POWER OF DATA TO PREVENT LOSSES

As we enter the era of big data and analytics, loss data, such as that contained within this report, is an invaluable resource that enables correlations to be identified between causes of losses, risk management practices, and possible outcomes. This will, in the future, allow for more detailed targeting of risk reduction and mitigation investment.

Despite the significant efforts in safety design and management systems, catastrophic incidents are still happening. Could it be that the industry is not learning lessons from the past? It is evident that losses with common causes continue to occur across various parts of the industry.

In many of the cases examined in this report, minor incidents have escalated in an uncontrolled manner to result in major events. The consequences of those events were not significantly mitigated and resulted in major physical damage and other significant impacts.

As such, we hope that this publication can act as a spur to organizations to collect and share information on industry losses by demonstrating the value of being able to learn from the experience of others to prevent the reoccurrence of accidents and incidents.

USING RISK ENGINEERING SURVEYS TO EVALUATE RISKS

Examining past events can help the industry think about the barriers that would have prevented and mitigated these losses. This understanding can then be used to identify potential major hazard exposures, as well as the measures required and their effectiveness in reducing the likelihood of the loss. This also informs energy industry insurance engineers in their assessment of the adequacy of risk controls on sites when undertaking a risk engineering survey.

A risk engineering survey of the sites covered by a policy is a key part of the placement of energy industry insurance. These surveys, conducted by professional engineers, review the hardware, software, and emergency response capabilities in relation to the insurances in place to transfer the risk exposure. The surveys also collect data to enable the calculation of a maximum property damage loss value (normally called the property damage estimated maximum loss). Depending on the insurance products in place, maximum loss values will also be estimated for other exposures (for example, business interruption and machinery breakdown).

Risk engineering surveys also routinely result in the survey team making recommendations to the site managers to improve risk management practices. Recommendations should be linked to the relevant insurances being purchased for the exposed site and should - when implemented - result in a significant reduction in the likelihood of a major loss occurring, or reduction in the foreseeable consequences of a loss. They are typically linked to the site hardware, management systems, or emergency response arrangements. They should also be practical and proportionate, considering the risk profile of the site and the scale of the potential risk benefits.

INSURANCE MARKET WORKS TO IDENTIFY CRITICAL RISK TOPICS

Members of the London insurance market organization the Lloyd's Market Association (LMA) have undertaken work to identify the key scenarios and failures associated with the major energy industry losses that have resulted in large insurance claims. This work has been used to help identify the critical topics to be focused on during risk engineering surveys. A paper summarizing the work was presented at the international process safety conference Hazards 27 in Birmingham, UK in 2017.[1]

This analysis used a slightly different set of data than that presented in this document, with a shorter time frame (20 years), only considering onshore losses, not including natural catastrophe events, and including business interruption in the loss values applied.

The analysis of the losses highlights some dominant themes. Approximately 43% of the losses were identified as being the result of mechanical integrity failure, and this percentage was higher for the losses on oil refineries. Of these mechanical integrity failures, 70% were identified as being as a result of corrosion of process piping, primarily due to internal corrosion. Where external corrosion was a cause, it was as a result of corrosion under insulation. A significant proportion of these mechanical integrity failures are identified as being a result of an inadequate or

1 Jarvis, R. and Goddard, A. "An Analysis of Common Causes of Major Losses in the Onshore Oil, Gas and Petrochemical Industries", I.Chem.E, Symposium Series No. 162, Hazards 27. Paper 34.

incomplete inspection program, or failure to manage construction materials and quality assurance.

Other topics identified as important contributors to losses include:

- Inadequate hazard identification.
- Inadequate risk assessment of safety critical tasks (for example, assessment of plant start-up to develop the procedure).
- Reliance on remotely operated valves for safe isolations.
- Failure to identify safety critical devices.

Engineers should continue to analyze the experience of accidents and near-miss events to identify any common issues or causes. This demonstrates barriers that must be in place and working effectively to prevent and mitigate major accidents.

This review of the lessons from losses, and assurance of the adequacy of the measures in place, is an important component of any integrated process safety management system. It confirms that the measures are focused on the correct areas to control the risk of accidents.

IMPROVING PROCESS SAFETY PERFORMANCE BY LEARNING FROM LOSSES

The following examples of major loss events provide valuable lessons for energy risk mitigation in the future.

PIPER ALPHA

This year sees the 30th anniversary of the Piper Alpha disaster in the UK North Sea that resulted in the death of 167 offshore workers. As a result of the loss, and the subsequent public inquiry led by the Honourable Lord Cullen, there were major changes to the regulation of safety in the UK Continental Shelf oil industry and significant improvements in the culture of loss prevention and process safety.

The recommendations from the Cullen Report, published after the public inquiry, include requirements to improve the safety management systems, as well as more specific recommendations relating to engineering hardware measures. These critical findings continue to inform the scrutiny of major accident hazard plans carried out by insurance industry engineers.

The Piper Alpha disaster was a demonstration of the importance of clear communication between operating shifts, recording and understanding the status of equipment under maintenance, and the major loss mitigation benefits of remotely operated valves to isolate the flow of large inventories of hazardous flammable materials.

Shift handover, permit to work, and remotely operated isolation valves are all topics that are routinely reviewed during an insurance risk survey of an energy industry asset to determine their adequacy and effectiveness in preventing and mitigating accidents. These topics may also result in risk improvement recommendations, if the standards observed are less than that considered necessary to adequately control the risks.

MILFORD HAVEN

The major accident on the oil refinery in Milford Haven in the UK in 1994 was compounded by the overwhelming number of alarms received in the control room by the panel operators, which significantly hindered their ability to correctly diagnose what was occurring. This resulted in a catastrophic failure of the flare system, the release of a cloud of flammable vapor, and subsequent vapor cloud explosion which caused major damage to the refinery.

On sites where the control rooms have not been subject to effective alarm rationalization, risk engineering surveys often recommend an alarm study to eliminate unnecessary alarms and ensure that, in the event of a serious incident, panel operators will not be subject to a flood of alarms blinding them to the cause of the upset and preventing effective and appropriate response.

DEEPWATER HORIZON

Following the Deepwater Horizon/ Macondo loss in the Gulf of Mexico in 2010, which resulted in 11 fatalities, the US Chemical Safety and Hazard Investigation Board (CSB) carried out a thorough investigation and published a comprehensive report. The report included several recommendations, with the overall goal of reducing the risks of major accidents in offshore drilling to a level as low as reasonably practicable (ALARP). For example, the recommendations relating to the management of blow-out preventers in order to ensure that there is a high reliability that they will operate on demand are typical of the type of recommendation that would be made following a risk engineering survey.

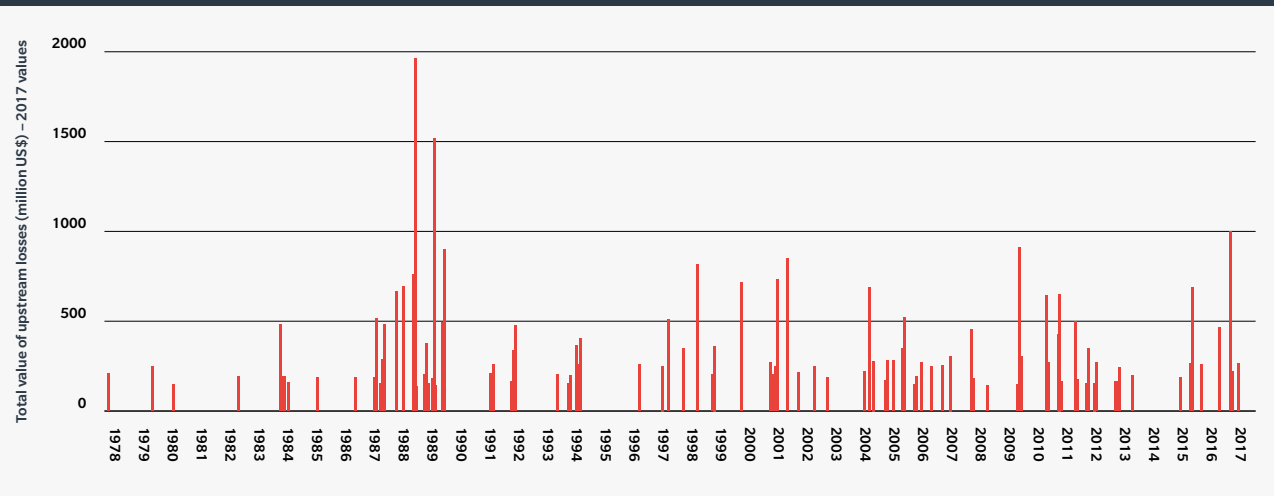
BIG SPRING

The refinery loss at Big Spring in the US in February 2008 is believed to have been as a result of the failure of a propylene pump leading to the release of a vapor cloud of light hydrocarbon that found a source of ignition, resulting in a vapor cloud explosion.

The design of the pump – a long-shaft vertical-buried can pump – is common in refinery operations for the transfer of low flash-point liquids. Insurance industry risk engineers carrying out surveys found that there was no common practice for the inspection and maintenance of the pressure containment envelope for pumps of this design, and, in some cases, it was found that the pump barrels had never been inspected since they were installed.

Following the experience from the Big Spring incident, it is now common practice to examine the inspection and maintenance regimes for vertical can pumps to ensure the management of their long-term integrity.

FIGURE 1 DISTRIBUTION OF THE 100 LARGEST LOSSES BY YEAR
Source: Marsh Research



DOWNSTREAM LOSSES – 2016 - 2017

There has been a significant spike in the number of high-value downstream losses over the past two years. The insurance industry is also responding to a large number of losses which, although not large enough to make the 100 Largest Losses list, have had a high impact on the global energy industry.

NOTABLE LOSSES IN THE DOWNSTREAM ENERGY SECTOR

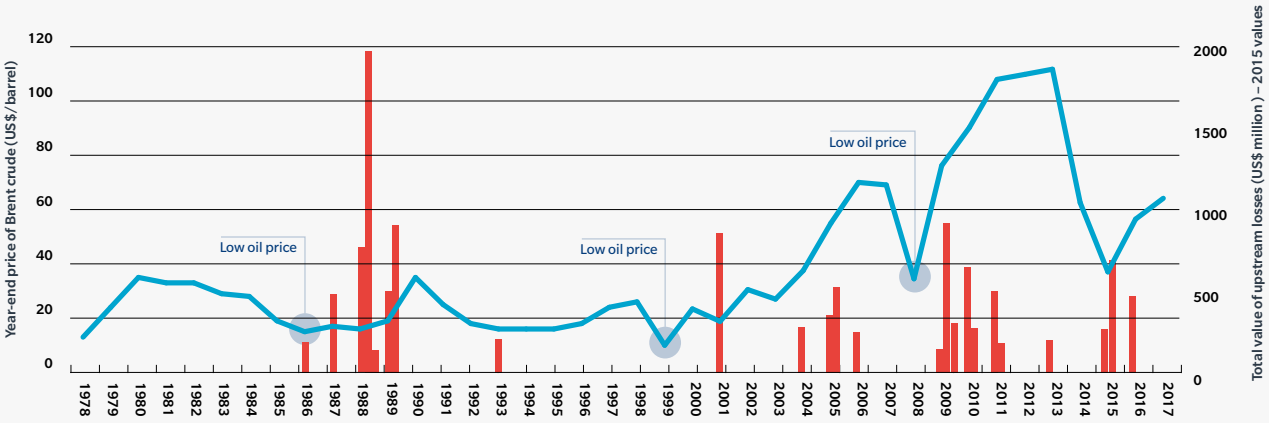
YEAR	LOCATION	LOSS DESCRIPTION	LOSS ESTIMATE (PROPERTY DAMAGE PLUS BUSINESS INTERRUPTION) US$ MILLION
2016	GERMANY	PETROCHEMICALS	500
2017	IVORY COAST	REFINERY	210
2016	US	GAS PLANT	100
2016	THAILAND	PETROCHEMICALS	95
2016	BAHRAIN	REFINERY	90
2017	JAPAN	REFINERY	85
2016	RUSSIA	REFINERY	80
2017	US	PETROCHEMICALS	67
2017	NORWAY	CHEMICALS	46

There are no obvious common themes driving these; the recent downstream losses have occurred across refining, petrochemicals, chemicals, and oil sands operations.

THE IMPACT OF THE PRICE OF OIL

In the 24th edition of *100 Largest Losses*, we commented on the historical correlation between low oil prices and loss trends in the hydrocarbon industry. The graph of crude oil price and upstream energy losses shows some correlation, with some major losses occurring in the years following significant reductions in the oil price. At the time of publication of the 24th edition, the price of oil stood around US$40/bbl, the lowest point since 2005. As we prepare this edition, the Brent crude oil price stands at just below US$70/bbl. There has been a fairly steady rise over that two-year period.

FIGURE 2 CRUDE OIL PRICE VERSUS UPSTREAM LOSSES BY YEAR – 1974-2015
Source: Marsh Research



The downstream sector is more insulated from variations in crude prices than the upstream businesses. Downstream margins are positively affected as the drop represents a potential reduction in feedstock costs. Indeed, during this period of commercial opportunity, Marsh has noted an increase in the number of downstream sites that have extended shutdowns and turnaround maintenance intervals. Coupled with the substantial cost saving programs taken by many organizations since 2015 (which saw major reductions in investments and in the working population), it's not unreasonable to ask if these are factors that have contributed to the spike in losses.

It was reported that US refinery throughput growth rates slowed from 1.8 million barrels per day in 2015 to 0.6 million barrels per day in 2017 (increase in the daily production capacity of US refineries over the year). However, it was also reported that US refinery utilization increased and at the end of 2017 was at 96.7%, its highest level since 2005. It could be argued therefore that US refineries are being pushed to operate at greater capacity and that increase in demand is not being addressed through investment in new refinery projects.

SPOTLIGHT

The Effect of Low Oil Prices on Upstream Assets

In the upstream sector, lower oil prices have led to the divestment by some of the oil majors of mature assets that are no longer giving a high rate of return on investment, as they develop projects in newer oil and gas producing regions. In many cases, this has led to older assets being taken over by smaller organizations, sometimes with limited previous corporate experience in the oil and gas sector. It is important that these new entrants maintain the competency to understand the risks associated with the assets that they have acquired.

NATURAL CATASTROPHES LEAD TO SIGNIFICANT LOSSES IN NORTH AMERICA

Following several benign years for natural catastrophes in North America, 2017 entered history as a significant loss year, with the energy industry being affected by hurricanes, severe weather, storms, flooding, and wildfires. Insured losses from natural catastrophes last year are estimated to have reached a record amount of US$135 billion globally.[2] Such events have caused physical damage and business interruption for the energy industry.

The 2017 Atlantic hurricane season heated up after a benign few years, with several major storms affecting the US East Coast and Caribbean, resulting in business interruption and property damage in the oil and gas sector. Hurricane Harvey, which made landfall in the Texas Gulf Coast as a Category 4 storm on the Saffir-Simpson scale, caused significant flooding to local refineries in the area.

Much of the US refining capacity, as well as a significant amount of petrochemical and LNG production, is concentrated along the Gulf Coast, meaning losses and supply chain disruption is a particular worry in this region. As a result of the storm, approximately 22% of US refinery capabilities were shut down due to flooding,[3] leading to business interruption and property damage losses for the downstream sector. For the upstream sector, crude oil production in the region slowed due to Harvey, but the impact was not as severe as in the downstream sector.

Individual losses from 2017 hurricanes failed to make the 100 Largest Losses, however, it should be noted that this does not include business interruption impacts, which was the most significant component of many of the losses. Such events also bring into focus the risks that the energy industry faces from flooding; after all, as the 100 Largest Losses highlights, some of the largest losses have occurred as a result of flooding.

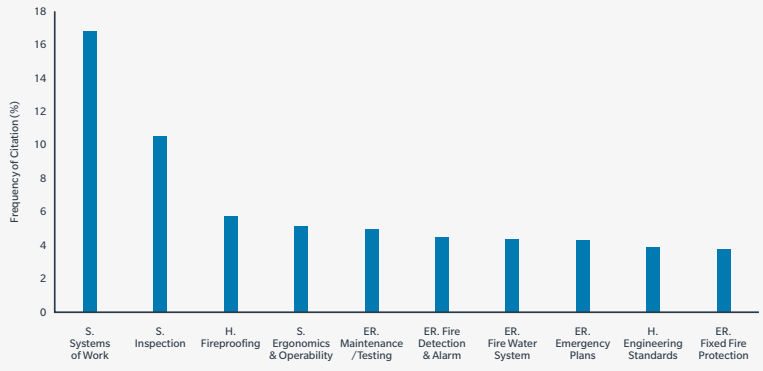
Elsewhere in North America, the worst year on record for wildfires in British Columbia, Canada[4] led to firms having to temporarily shut down natural gas wells, pipelines, and other facilities as a precaution where wildfires came dangerously close to operations. For energy companies, property losses remained low, but the closures led to costly business interruption.

TRENDS IN RISK RANKING

Analysis of risk improvement recommendations made during the course of engineering surveys over the past two years provides an indication of the risk control measures that were considered as being below the best practices in industry. The dominant topics of the recommendations are "systems of work" (for example, permit to work, shift handover communication, and management of change) and "inspection" (for example, staffing levels, competency, philosophy, and data analysis).

Focus on "systems of work" as cited in loss reports reflects their critical importance to the safe operation of energy facilities. Furthermore, the study by the Lloyd's Market Association cited earlier in this document concluded that "mechanical integrity failure" was responsible for 57% of man-made losses. Given these concerns, and combined with high operating rates, reduced staffing levels, and other cost saving programs, operators must maintain high levels of monitoring and vigilance to ensure that asset integrity is being maintained and accidents are eliminated.

FIGURE 3 **10 Most Commonly Cited Topics, Full Dataset (By %)**
Source: Marsh



2 Munich Re. "Natural catastrophe review: Series of hurricanes makes 2017 year of highest insured losses ever", available at https://www.munichre.com/en/media-relations/publications/press-releases/2018/2018-01-04-press-release/index.html, accessed 13 February 2018.

3 Platts. "Oil factbox: USGC refinery outages, port closures continue to increase Aug 30", available at https://www.platts.com/latest-news/oil/newyork/oil-factbox-usgc-refinery-outages-port-closures-26796285, accessed 13 February 2018.

4 Government of British Columbia. "Wildfire Statistics", available at https://www2.gov.bc.ca/gov/content/safety/wildfire-status/wildfire-statistics, accessed 13 February 2018.

NEWLY QUALIFYING LOSSES SINCE MARCH 2016

Figure 4 shows the largest property damage losses to have occurred in the hydrocarbon industry since the publication of the 24th edition of the *100 Largest Losses*. We have also identified the 20 largest losses in the industry, according to Marsh data (Figure 5).

The following pages provide insight on the distribution of the 100 largest losses by year (Figure 6) and by geographical distribution (Figure 7). Further details of these losses are available in the relevant sections of the publication.

FIGURE 4 LARGEST LOSSES 2016-2017
Source: Marsh Research

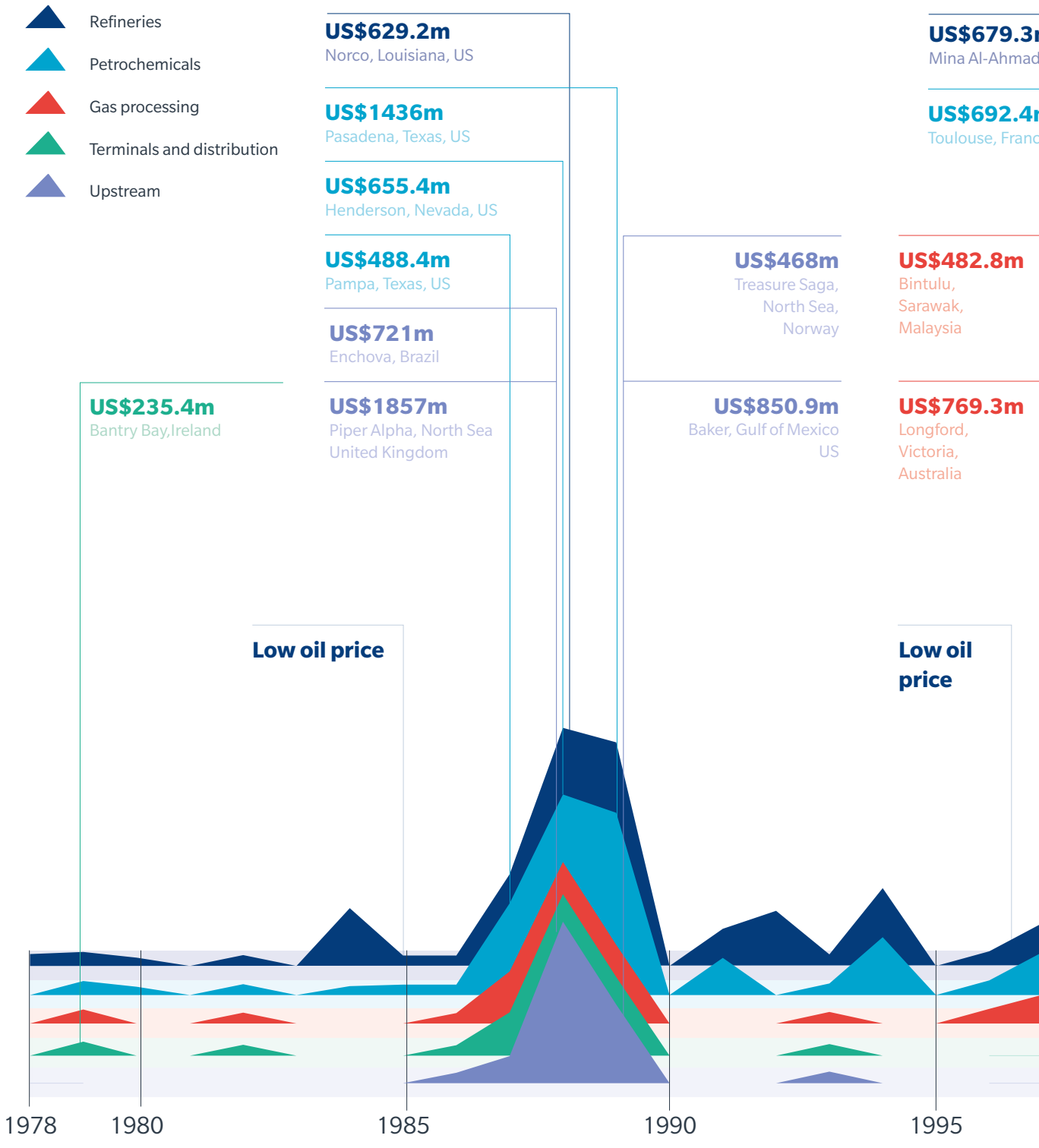
DATE	PLANT TYPE	EVENT TYPE	LOCATION	COUNTRY	PROPERTY LOSS (US$M)
02/11/2016	EXPLORATION AND PRODUCTION (E&P) OFFSHORE	MECHANICAL DAMAGE	JUBILEE FIELD	GHANA	450
12/01/2016	REFINERY	FIRE	SANNAZZARO DE' BURGONDI	ITALY	250
01/11/2017	REFINERY	FIRE	RUWAIS, ABU DHABI	UNITED ARAB EMIRATES	1,000+
01/30/2017	CHEMICAL	FIRE	PORI	FINLAND	267
03/14/2017	REFINERY	FIRE	FORT MCMURRAY, ALBERTA	CANADA	220

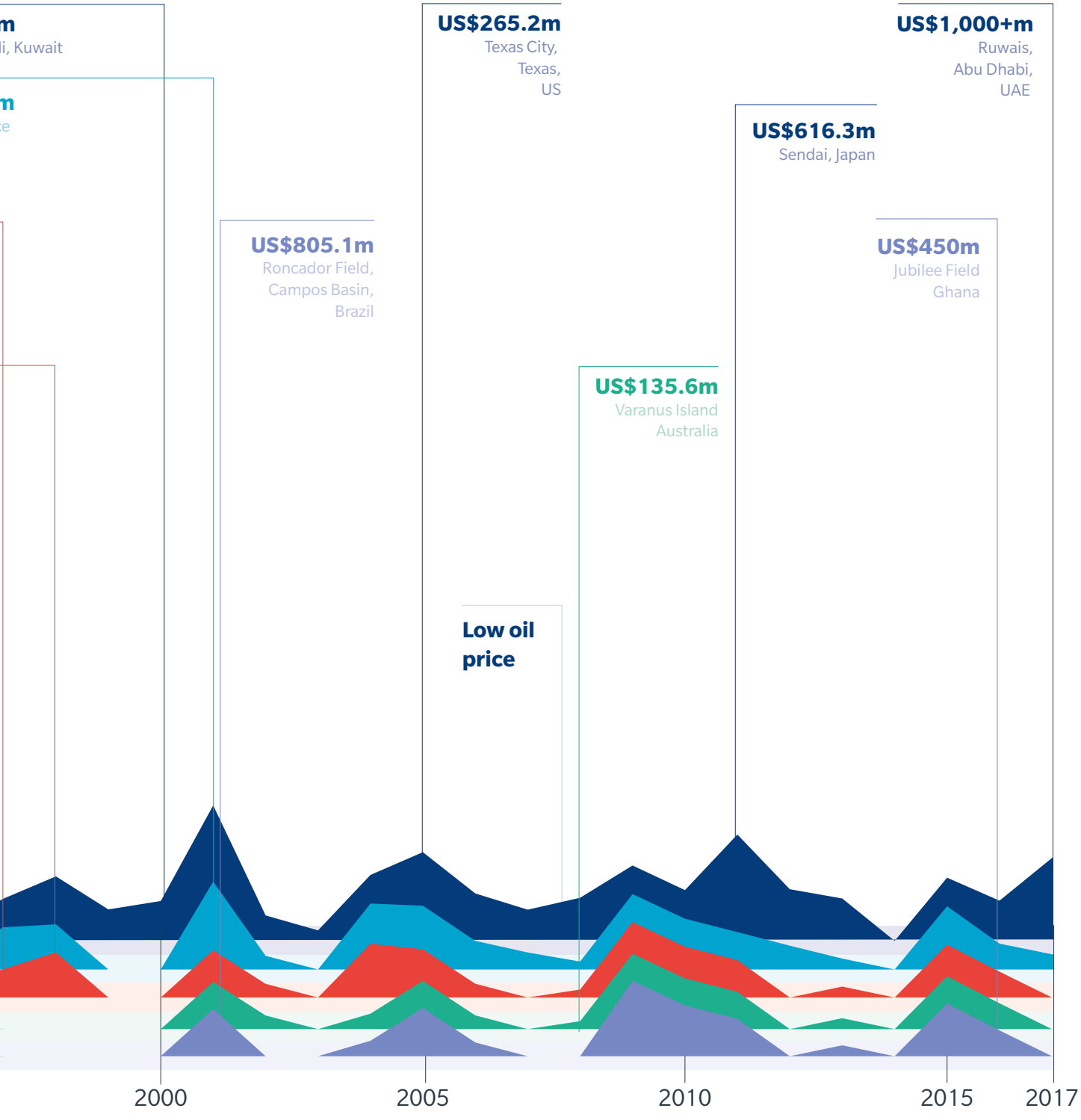
FIGURE 5 THE 20 LARGEST LOSSES 1978 - 2017
Source: Marsh Research

DATE	PLANT TYPE	EVENT TYPE	LOCATION	COUNTRY	PROPERTY DAMAGE1 (US$ M)
07/06/1988	E&P OFFSHORE	EXPLOSION, FIRE	PIPER ALPHA, NORTH SEA	UNITED KINGDOM	1,960
01/11/2017	REFINERY	FIRE	RUWAIS, ABU DHABI	UNITED ARAB EMIRATES	1,000+
10/23/1989	CHEMICAL	EXPLOSION, VAPOR CLOUD EXPLOSION (VCE)	PASADENA, TEXAS	UNITED STATES	1,520
06/08/2009	E&P OFFSHORE	BUSINESS INTERRUPTION	NORTH SEA	NORWAY	910
03/19/1989	E&P OFFSHORE	EXPLOSION, FIRE	BAKER, GULF OF MEXICO	UNITED STATES	900
03/15/2001	E&P OFFSHORE	EXPLOSION	RONCADOR FIELD, CAMPOS BASIN	BRAZIL	850
09/25/1998	GAS PROCESSING	EXPLOSION, VCE	SALE, LONGFORD, VICTORIA	AUSTRALIA	810
04/24/1988	E&P OFFSHORE	BLOWOUT	ENCHOVA, CAMPOS BASIN	BRAZIL	760
09/21/2001	FERTILIZER	EXPLOSION	TOULOUSE	FRANCE	730
06/25/2000	REFINERY	EXPLOSION, FIRE	MINA AL-AHMADI	KUWAIT	720
05/04/1988	CHEMICAL	EXPLOSION	HENDERSON, NEVADA	UNITED STATES	690
01/19/2004	GAS PROCESSING	EXPLOSION, FIRE	SKIKDA	ALGERIA	690
04/01/2015	E&P OFFSHORE	FIRE	ABKATUN, BAY OF CAMPECHE	MEXICO	690
05/05/1988	REFINERY	EXPLOSION, VCE	NORCO, LOUISIANA	UNITED STATES	670
03/11/2011	REFINERY	EXPLOSION, FIRE	SENDAI	JAPAN	650
04/21/2010	E&P OFFSHORE	EXPLOSION, FIRE	GULF OF MEXICO	UNITED STATES	640
07/27/2005	E&P OFFSHORE	EXPLOSION, FIRE	MUMBAI, HIGH NORTH	INDIA	520
11/14/1987	CHEMICAL	EXPLOSION, VCE	PAMPA, TEXAS	UNITED STATES	520
12/25/1997	GAS PROCESSING	EXPLOSION	BINTULU, SARAWAK	MALAYSIA	510
02/04/2011	E&P OFFSHORE	BUSINESS INTERRUPTION	NORTH SEA	UNITED KINGDOM	500

5 Inflated to December 2017 values. Values are ground-up, property damage only.

FIGURE 6 PROPERTY DAMAGE VALUE OF 100 LARGEST LOSSES BY SECTOR
Source: Marsh Research

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US$135.6m
Varanus Island
Australia
US$616.3m
Sendai, Japan
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Ruwais,
Abu Dhabi,
UAE
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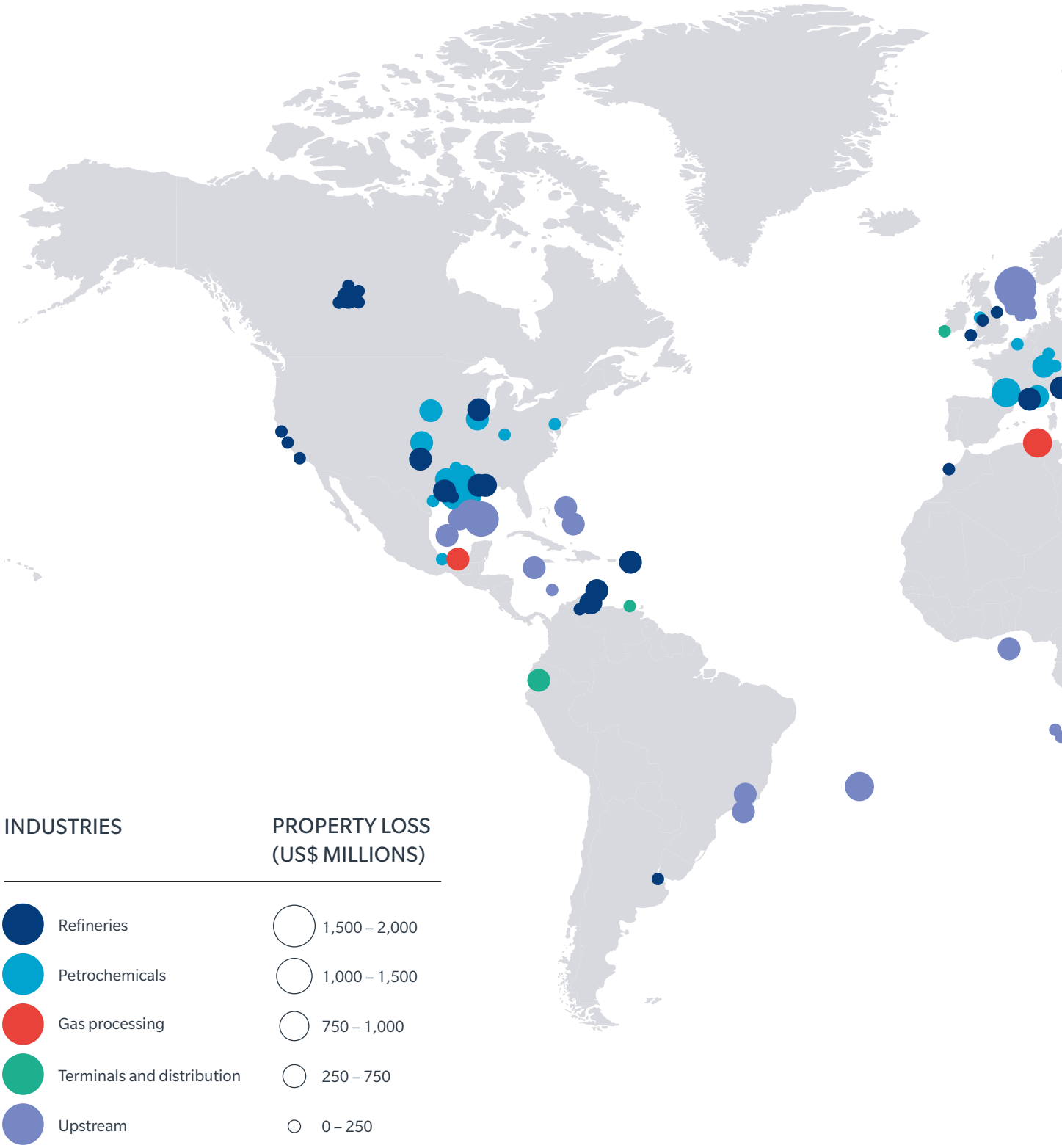
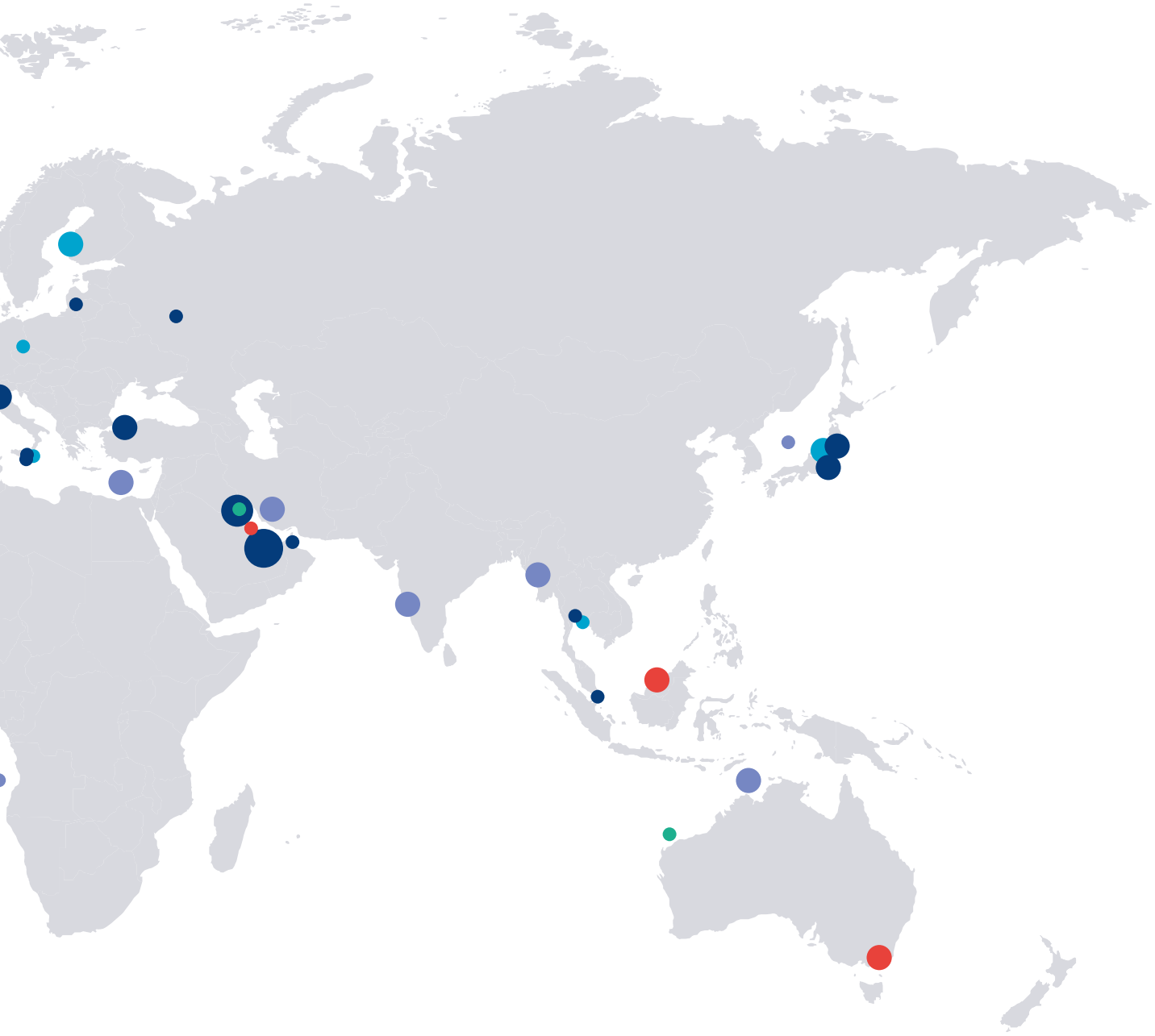
2010
2015
2017

FIGURE 7 GEOGRAPHICAL DISTRIBUTION OF 100 LARGEST LOSSES
Source: Marsh Research



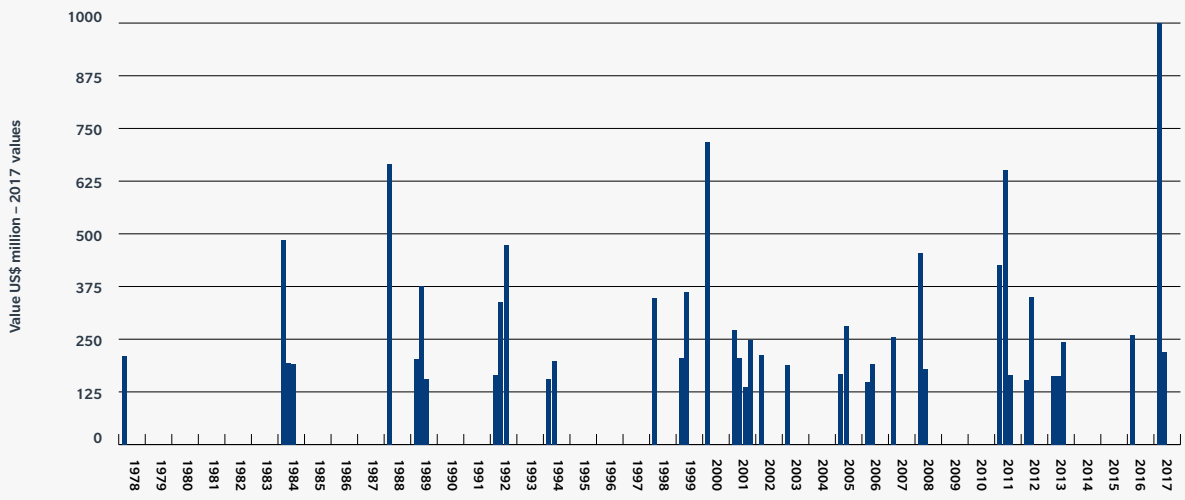


REFINERIES

There continue to be major losses in the refining industry, with recent history dominated by a very large loss on a newly commissioned refinery in the Middle East. The size of these losses is often impacted by the complexity of the refinery, its level of integration, and the concentration of property value around the location of the incident. New refineries will increasingly employ technically complex, high-value process equipment to maximize the yield of valuable products from each barrel of oil processed. It is important, therefore, that passive protection measures such as lay-out and separation, as well as active risk mitigation measures are still considered in the design of new refineries to minimize the potential loss in the event of fires and explosions.

There also continues to be a large number of oil sand industry losses. When fires occur on these major plants, they frequently result in multi-million dollar losses because of the size and value of the plants. The frequency of fires reflects the challenging environments in which these units operate and the aggressive nature of the materials being processed – they are physically located much closer to upstream operations than conventional refineries, and there is less intermediate processing of the raw materials.

FIGURE 8 REFINERY PROPERTY DAMAGE LOSSES BY YEAR
Source: Marsh Research



DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ESTIMATED CURRENT VALUE US$ MILLION
05/30/1978	EXPLOSION	TEXAS CITY, TEXAS US	55	211

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 rocketed pieces of the sphere throughout the plant. Within the next 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 due to a boiling liquid expanding vapor explosion (BLEVE). Pieces of the tanks traveled in all directions, falling into 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.

07/23/1984	EXPLOSION	ROMEOVILLE, ILLINOIS US	191	484

Just prior to the rupture of a 55-feet-tall, 8.5-feet diameter monoethanolamine absorber column, a refinery operator noted a six-inch-long horizontal crack at a circumferential weld which was leaking propanes. 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 massively. Propane at 200 psig at 100ºF 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 a repair to the column 10 years earlier. The vessel was constructed of one-inch-thick SA 516 Gr 70 steel plates rolled and welded with full penetration submerged arc joints, but without post-weld heat treatment.

This explosion resulted in severe fires in the unsaturated gas plant, and the FCC and the alkylation units. After about 30 minutes, a BLEVE occurred in a large process vessel in the alkylation unit. One piece of this vessel traveled 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 where it landed.

The first explosion, believed to be from an unconfined vapor cloud, broke windows up to six miles from the plant, caused extensive structural damage to refinery service buildings and disrupted all electric power at the refinery, rendering a 2,500 US gallons per minute electric fire pump inoperable. One explosion sheared off a hydrant barrel, resulting in a reduction of fire water pressure from the two 2,500 US gallons per minute diesel engine driven fire pumps, which were operating. 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 gallons/min fireboat eventually provided water at pressures sufficient for fire fighting.

08/15/1984	FIRE	FORT MCMURRAY, ALBERTA CANADA	75	190

Erosion failure in a 10-inch-diameter slurry recycle oil line in an 82,000 bbl per day fluid bed coking unit released liquids close to their auto ignition temperature. A vapor cloud which covered a large area ignited almost immediately resulted in a ground fire covering a large area which resulted in the failure of six or seven additional lines. The fire eventually extended over a 150-feet-diameter area with damage up 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 gasoil stripper, 15,000 hp 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, which supplied the turbine drivers of the compressors, ruptured, hampering fire fighting efforts.

12/13/1984	EXPLOSION	AMUAY VENEZUELA	75	180

A straight run of eight-inch-diameter line carrying hot oil from the high pressure separator to the low pressure stripper in a refinery hydrodesulfurizer fractured circumferentially in the parent metal in the heat zone about 1.5 inches from a weld. Hot oil at 700 psi and 650ºF sprayed across the roadway into the hydrogen units where ignition occurred.

An intense fire around the pipe rack in the hydrogen plant caused a 16-inch-diameter gas line to rupture, adding a second blow torch to the fire. More pipes ruptured with explosive force in adjacent areas.

The fire resulted in a crash shutdown of the entire 600,000 bbl/d refinery. After six and a half hours, the fire was extinguished. Damage was extensive. The three hydrogen plants and the four hydrodesulphurization (HDS) units were heavily damaged or destroyed. Before the loss, the line which failed was judged as having excessive vibration. It is believed that the hot oil line failed due to fatigue, considered, in turn, to be largely due to hydrogen embrittlement.

DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ESTIMATED CURRENT VALUE US$ MILLION
05/05/1988	EXPLOSION	NORCO, LOUISIANA US	288	665

Operations were normal in a 90,000 bbl per day 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 20,000 pounds 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 at 130ºF) and the Depropanizer accumulator depressurized through the opening. Ignition of the vapor cloud probably was caused by the FCC charge heater. The initial blast destroyed the FCC control building and toppled the 26-feet-diameter main fractionator from its 15-feet-high concrete pedestal. The column separated from its 10-feet-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 up to six miles away. The FCC unit eventually was demolished and a new unit was constructed.

A preliminary report stated that the failed elbow was located downstream of the 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 unexpectedly high localized corrosion rates.

04/10/1989	FIRE	RICHMOND, CALIFORNIA US	90	202

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 steel skirt for this reactor, which was between 10 and 12 feet in diameter and had a wall thickness of seven 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 incident, 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.

09/18/1989	MECHANICAL DAMAGE, PRODUCTION LOSS	ST CROIX, VIRGIN ISLANDS US	167	375

Hurricane Hugo struck this 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 miles per hour was reported for this 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 seven days a week for 15 weeks to remove the asbestos debris from the refinery at a substantial extra expense.

A contractor specializing in the construction of atmospheric storage tanks worked for more than one year rebuilding the 14 storage tanks damaged in the tank farm area.

DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ESTIMATED CURRENT VALUE US$ MILLION
12/24/1989	EXPLOSION, VCE	BATON ROUGE, LOUISIANA US	69	155

An eight-inch-diameter pipeline operating at approximately 700-pounds-per-square-inch ruptured, releasing a mix of ethane and propane. The record low temperature of 10°F for the region is believed to have contributed to the rupture. After a few minutes, the resulting release was ignited, causing a vapor cloud explosion.

The explosion shattered windows up to six miles away and could be felt as far as 15 miles away. Seventeen additional pipelines, in a pipe rack containing 70 lines, were ruptured by the explosion. The resulting fire involved two large storage tanks holding 3.6 million gallons of diesel, 12 small tanks containing a total of 882,000 gallons of lube oil, and two separator units.

The explosion resulted in the partial loss of electricity, steam, and fire water for the refinery, since two power lines, two steam lines and a 12-inch diameter fire water line were located in this pipe rack. Upon the initial explosion, the lines for the dock fire pumps were damaged. Therefore, the water for fire fighting had to be supplied with the remaining plant fire pumps and municipal fire trucks taking draught from alternate sources.

Approximately 48,000 gallons of aqueous film-forming foam (AFFF) concentrate, 200 fire brigade members, and 13 pumper units were used during the fire fighting effort, which was successful in extinguishing the fire approximately 14 hours after the initial explosion. Because of this incident, the refinery was completely shut down for three days and operated at reduced capacity for an additional three weeks.

10/08/1992	EXPLOSION	LOS ANGELES, CALIFORNIA, US	78	165

An explosion originating in the hydrogen processing unit occurred in this 75,000 bbl/d refinery. Extensive damage was caused to the hydrocracker, hydrodesulphurization, and hydrogen processing units by the explosion and subsequent fires. The fires were fueled by hydrocarbons released from the damaged process column and equipment. The explosion, which damaged nearby buildings and shattered windows several miles away, 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 a 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 relevant to the incident until after the failure of the pipe elbow. An inspection after the failure found the line at nearly full design thickness a short distance away from 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 utilizing 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 Harbor. 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.

10/16/1992	EXPLOSION	SODEGAURA JAPAN	161	339

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

The hydrodesulphurization unit was being restarted following catalyst exchanging work when plant personnel noticed that hydrocarbon was 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 and 45 minutes by firefighters using 15 fire trucks.

DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ESTIMATED CURRENT VALUE US$ MILLION
11/09/1992	EXPLOSION	LA MEDE FRANCE	225	474

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

The initial vapor cloud explosion and several subsequent lesser explosions could be heard in Marseille, approximately 18 miles from the refinery. 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 this refinery, which covers an area of about 250 hectares. The gas plant, FCC unit, and associated control building were completely destroyed by this incident. Two new process units, which were under construction and scheduled to come into operation in 1993, were seriously damaged. Outside of the refinery, 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 more than 250 fire fighters from three neighboring industrial sites and four nearby towns were used for more than six hours to bring this 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.

07/24/1994	FIRE	MILFORD HAVEN UNITED KINGDOM	78	154

A severe thunderstorm passed over this refinery between 07:20 and 09:00 on July 24, 1994. Lightning strikes resulted in a 0.4 second power loss and subsequent power dips throughout the refinery. Consequently, numerous pumps and overhead fin-fan coolers tripped repeatedly, resulting in the main crude distillation column pressure safety valves lifting. Major process unit upsets occurred in other refinery units including those within the 90,000 bbl per day FCC complex.
The refinery crude unit was shut down following ignition of vapor escaping from the main crude column pressure safety valves by a subsequent lightning strike. All of the units in the cracking complex, except the FCC unit itself, were also shut down. However, a process upset in the FCC unit's gas recovery section ultimately led to a high liquid level in the on-plot flare drum and several shutdowns of the wet gas compressor, together with other process anomalies.

As a result of the wet gas compressor shutdown, there was a large vapor load on the FCC flare system, which lead to a high liquid level in the on-plot flare drum. When the hydrocarbon liquid overflowed into the outlet line of this drum, the line ruptured due to mechanical shock. A pulsing leak appeared at the flare drum discharge elbow where the outlet line had ruptured and fell to the ground.

The hydrocarbon liquid and vapor mixture released from this flare system formed a vapor cloud that drifted through the process area prior to being ignited by a heater. The explosion was centered in the process area approximately 360 feet (110 meters) from the FCC on-plot flare drum.

Following the explosion, isolated fires continued to burn at locations within the FCC, butamer, and alkylation units. In view of the entrained hydrocarbons in damaged areas of the plant and a non-operative flare system, these small fires were allowed to burn out under controlled conditions with the last fire being extinguished on the morning of July 27, 1994. The fire fighting was handled by the refinery emergency services, with assistance from the Dyfed County Fire Service.

As a result of this incident, an estimated 10% of the total refining capacity in the UK was lost until this complex was returned to service.

08/07/1994	EXPLOSION, FIRE	RYAZAN RUSSIA	100	199

This event occurred on a crude unit at this 360,000 bbl per day refinery. A furnace was undergoing 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 to have been the likely causes.

DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ESTIMATED CURRENT VALUE US$ MILLION
09/01/1998	HURRICANE/FLOOD	PASCAGOULA, MISSISSIPPI US	190	349

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. In all, some 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.

03/25/1999	EXPLOSION	RICHMOND, CALIFORNIA US	113	205

This explosion was caused by the failure of a valve bonnet in a high-pressure section of a 60,000 bbl-per-day 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. Approximately 300 fire fighters and 33 fire trucks participated in the two and a half-hour effort to control the fire. Foam concentrate consumed totaled 3,200 US gallons. The hydrocracker was out of service for 12 months.

08/17/1999	EARTHQUAKE	KORFEZ, GULF OF IZMIT TURKEY	200	362

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 this 226,000 bbl-per-day refinery. Fires also broke out on several storage tanks on the site. 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, firefighting efforts were limited to attempts by aircraft to drop chemicals on the fires. The US and several other countries sent foam supplies, personnel, and equipment to fight the fires. Damage to the refinery included total loss of six storage tanks, deformation of a further four storage tanks, and approximately 50% damage to other floating roof tanks. Damage to process units included the fire on the crude distillation unit, damage to a reformer, and damage to several connecting pipelines. All employees were evacuated. Airplanes were used to spray chemicals to extinguish the fire because of a shortage of water due to broken main.

06/25/2000	EXPLOSION	MINA AL-AHMADI KUWAIT	412	718

An explosion occurred when employees were attempting to isolate a leak on a condensate line between the natural gas liquid (NGL) plant and the refinery. 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 initial investigation into the loss indicated a lack of inspection and maintenance of the condensate line, which was not owned by the refinery. A lack of clear understanding of the ownership of the line is thought to have delayed the isolation of it.

04/09/2001	FIRE	WICKLAND, ARUBA DUTCH ANTILLES	159	271

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, heat restricted fire fighting access, inadequately trained fire brigade personnel, and damage to the firewater distribution system further hindered extinguishing the fire in a timely manner. The fire was spread by the firewater application, and was finally extinguished with the help of the local fire department.

04/16/2001	EXPLOSION, FIRE	KILLINGHOLME HUMBERSIDE UNITED KINGDOM	80	136

A blast occurred in the FCC light gas plant following the release of a six-metric-ton cloud of LPG from the de-ethanizer overhead line. An elbow in the overhead line failed due to corrosion as a result of water injection upstream.

The resulting explosion caused the rupture of a 14-inch gas line and reboiler return line released further eight-metric-tons of LPG. Both ruptures resulted in fire balls. The explosions caused major damage to buildings.

04/23/2001	FIRE	CARSON, CALIFORNIA US	120	204

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 approximately two months.

DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ESTIMATED CURRENT VALUE US$ MILLION
08/14/2001	FIRE	LEMONT, ILLINOIS US	145	247

The 160,000 bbl-per-day 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.

11/22/2002	EXPLOSION	PORT OF MOHAMMEDIA MOROCCO	130	213

Following torrential rain, rising floodwater allowed waste oil floating on the surface to be brought 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, two were killed, and a further three reported missing. Later reports said that two to three production units had been affected by the fire. The processing units affected were the crude unit, the 20,000 bbl-per-day vacuum distillation unit, the 24,000 bbl-per-day catalytic reformer unit, and the 24,000 bbl-per-day distillate hydrotreater. At the time, it was stated that the units not affected by the fire would restart within 15 days, although the other units would not be operational for a further eight to 12 months.

01/06/2003	EXPLOSION	FORT MCMURRAY, ALBERTA CANADA	120	189

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

01/04/2005	EXPLOSION	FORT MCMURRAY, ALBERTA CANADA	120	168

A fire broke out at the oil sands refinery in Upgrader 2, an area of the plant that converts bitumen into crude oil products. Approximately 250 people were evacuated from the plant, but no injuries were reported. The fire burned for nine hours before being extinguished. Witnesses reported two explosions minutes apart which 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 -35C. On February 3, 2005, the company announced that a ruptured cycle line was the most likely cause of the fire. Oil production was reduced from 225,000 bbl-per-day to about 110,000 bbl-per-day for about nine months.

03/23/2005	EXPLOSION	TEXAS CITY, TEXAS US	200	280

A total of 15 people were killed and 105 injured following an explosion at the 460,000 bbl-per-day 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 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 vicinity of the unit. There was a group of temporary buildings supporting planned turnaround activity on another unit located in close proximity to the blowdown stack, and many of the fatalities were attending a meeting in these buildings when the vapor cloud found a source of ignition and exploded.

04/30/2006	FIRE	PRIOLO, SICILY ITALY	110	147

Two firefighters were injured tackling a blaze at a refinery. The incident occurred when crude oil leaked from a pipe supplying the refinery from bulk storage tanks.

10/12/2006	EXPLOSION	MAZEIKIU LITHUANIA	143	191

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 shutdown completely and the refinery was left running but at a much reduced capacity. An investigation identified that the fire was caused by a leak from a branch on the column that was fabricated from an incorrect material.

DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ESTIMATED CURRENT VALUE US$ MILLION
08/16/2007	FIRE	PASCAGOULA, MISSISSIPPI US	200	255

A fire broke out in a crude unit of a 325,000 bbl/d refinery and burned for more than six hours. No injuries were reported. Company officials said a major portion of the refinery was able to continue to operate. The another crude unit at the refinery remained operational.

02/18/2008	FIRE	BIG SPRING, TEXAS US	380	454

An explosion at this 70,000 bbl-per-day oil refinery caused damage to the FCC, utilities, storage tanks, and asphalt unit. One employee was hospitalized for burns. Another person was injured when her car was struck by debris from the explosion on the nearby highway. There was a total of four injuries. A skeleton crew of just 40 people were on site because the blast occurred on a public holiday. There would typically have been about four times as many people on duty at the time of the explosion. The fire was brought under control the same day by the site's 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.

10/13/2008	EXPLOSION	PRIOLO GARGALLO. SICILY ITALY	150	179

An explosion and fire in a 562 megawatt (MW)-capacity integrated gasification combined cycle electricity generating plant at a refinery caused a fire in the gasification unit on a refinery. No one was injured as a result of the explosion and fire, but the loss resulted in the temporary closure of the refinery.

01/06/2011	EXPLOSION	FORT MCKAY, ALBERTA CANADA	385	425

An explosion occurred on this 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 normal shifts the following morning. The majority of the 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. Firefighting in freezing conditions caused additional damage.

03/11/2011	EXPLOSION	SENDAI JAPAN	590	651

A major explosion occurred at a 145,000-barrels-per-day 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 Sendai refinery originated from a land oil product shipping facility. Workers at the refinery were evacuated, and there was no capacity available to extinguish the fire.

Fire in the storage and shipping facilities had also damaged a 35,500 barrels-per-day FCC at the refinery.

09/28/2011	FIRE	PULAU BAKOM SINGAPORE	150	166

A fire broke out in a refinery, reported to have 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, and the company began steps to shut down the whole refinery. The fire was reported as finally extinguished late in the evening of the second day, about 34 hours after it was first reported. The production units on the refinery were progressively restarted, and all units were back in production by the end of 2011.

DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ESTIMATED CURRENT VALUE US$ MILLION
07/04/2012	FIRE	BANGKOK THAILAND	140	153

The explosion and fire occurred in the kerosene stripper of the crude distillation unit (CDU) at a 80,000 bbl-per-day refinery located in an industrial zone surrounded by residential areas. This resulted in fires in the area, but no injuries were reported. The refinery operator said it would postpone a maintenance shutdown at its refinery, set for late July, to reduce the risk of supply shortages as a result of the fire. The CDU damaged by the fire was replaced within three months.

08/25/2012	EXPLOSION	FALCON STATE VENEZUELA	320	349

A very 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 several leaks at the refinery in the previous year.

01/12/2013	FIRE	STANLOW, CHESHIRE UNITED KINGDOM	150	162

Refinery and local fire fighters spent more than six hours battling a fire on a large oil refinery. A warning was issued to local residents because of thick non-toxic smoke generated from a stack on the site. The fire is thought to have broken out in a furnace. No injuries were reported.

03/11/2013	FIRE	SOHAR OMAN	150	162

A fire broke out in a wet gas scrubber while heavy maintenance on a unit was being carried out. Personnel were evacuated from the site and there were no injuries. The site was conducting a planned shutdown and maintenance of the plant equipment including the polypropylene plant.

04/02/2013	EXPLOSION	LA PLATA DISTRICT, ENSENADA ARGENTINA	225	243

A fire broke out in the 188,000 barrels-per-day 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. There were two fires in the crude distillation unit (CDU), one in the coking plant and two in the topping distillation plant. The government agency said the incident had been caused by hydrocarbons exploding in one of the coke manufacturing furnaces. The furnaces had been shut down, but were still hot enough to ignite the hydrocarbon. It took eight hours to extinguish the fire and 10 hours before the incident was under control. There were no fatalities or injuries.

12/01/2016	FIRE	SANNAZZARO DE' BURGONDI ITALY	250	259

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.

01/11/2017	FIRE	RUWAIS, ABU DHABI UNITED ARAB EMIRATES	1,000+	1,000+

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. The value of the property damage loss is currently estimated to be in excess of US$1 billion.

03/14/2017	FIRE	FORT MCMURRAY, ALBERTA CANADA	220	220

A fire occurred on one of the two hydrotreaters on an oil sands upgrader facility. The fire was reported to be as a result of the failure of a pipe, resulting in a releaser of naphtha. One worker was seriously injured as a result of the fire, which was extinguished after two days.

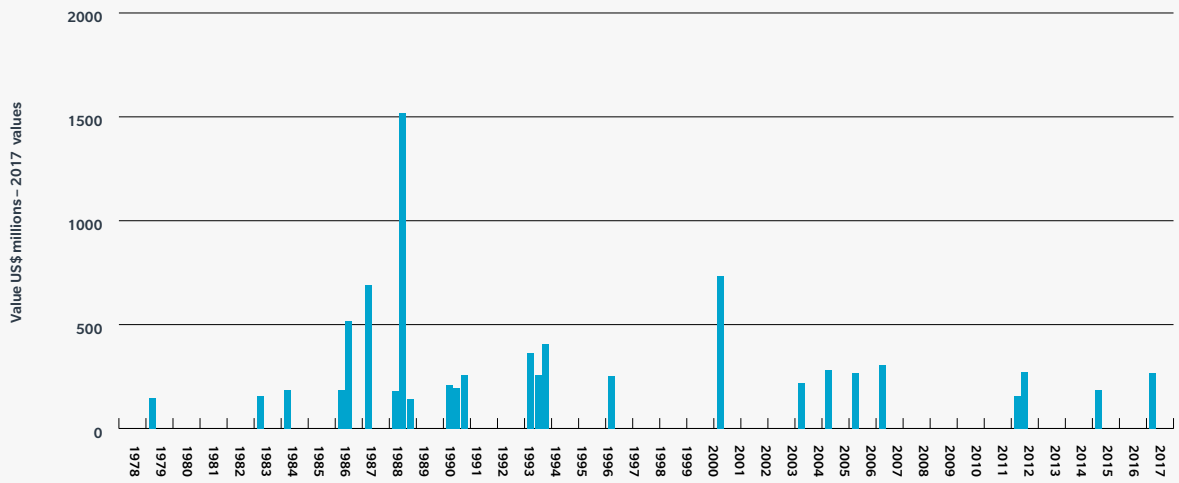
PETROCHEMICALS

The loss record for the petrochemicals industry is dominated by the disaster in Pasadena, Texas in 1989, the investigation of which had a major influence on the regulation of industrial safety in the US. However, there have been several major losses in Europe over the past few years.

These plants are often complex, integrated with concentrations of high value equipment and machinery, and typically operate at high pressures and temperatures. The materials that they process have normally been pre-processed, for example, they are supplied downstream of oil refineries. As a result, most of the contaminants will have been removed prior to receipt and they handle a feedstock with a consistent specification and quality.

Some of these plants are now aging, and many are designed to standards that do not reflect current best practices. For example, in a modern design, layout and drainage arrangements would remove flammable materials from hazardous areas, but older designs retain spillages close to the process plant. As a result, there is the potential for greater escalation, and greater damage, in the event that flammable liquids spill and ignite.

FIGURE 9 PETROCHEMICAL PROPERTY DAMAGE LOSSES BY YEAR
Source: Marsh Research



DATE OF LOSS	EVENT TYPE	SITE TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ADJ PROPERTY US$ MILLION
04/30/1980	EXPLOSION	CHEMICAL	NEWCASTLE, DELAWARE US	45	147

An explosion occurred while polypropylene polymerization was being carried out in three parallel reaction trains (A,B,C) at this petrochemicals plant. The reactants were carried in a hexane solvent with several catalysts and processed onto pellets.

As a result of a maintenance error, a 100 millimeter plug valve was blown out of a line in train A, releasing hydrocarbons and polymers. The vapor cloud rose upward, carried by a light wind into the finishing building, where the explosion occurred.

Further fires resulted from broken flammable liquid lines in the process area and from the released products in the finishing area. The loss included the three trains, the control building, the compressor building, and part of the finishing building.

09/15/1984	FIRE	CHEMICAL	WARRINGTON, CHESHIRE UNITED KINGDOM	62	158

A fire started in the oxidization plant. Some 130 firemen using 25 appliances controlled the blaze after four hours. The local railway line, ship canal, and roads were closed and 200 people evacuated. The plant was rebuilt with larger spacing to obtain authorities approval.

05/19/1985	EXPLOSION	CHEMICAL	PRIOLO ITALY	74	185

A faulty temperature probe on a 600,000-metric-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 de-ethanizer column. The source of fuel was believed to have been a flange at the de-ethanizer 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 traveling 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, which apparently were 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.

A few 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 fire brigade brought the fire under control over 40 hours and finally extinguished it four days after the initial ignition.

07/03/1987	EXPLOSION	CHEMICAL	ZWIJNDRECHT, ANTWERP BELGIUM	78	187

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

11/14/1987	EXPLOSION	CHEMICAL	PAMPA, TEXAS US	215	516

An explosion occurred in an air line in a reactor used for the liquid phase oxidation of butane as it was being started up. The explosion ruptured the external portion of the air line to the reactor, allowing the reactor contents to vaporize and form a cloud. The vapor cloud drifted and ignited about 25 to 30 seconds after the initial release. There was extensive property damage in the immediate area as a result of the vapor cloud explosion 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.

05/04/1988	EXPLOSION	CHEMICAL	HENDERSON, NEVADA US	300	693

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 was thought to be a fire in a batch dryer. The initial explosion was at 11:53 and was equivalent to 108 tons of TNT, with a second explosion four minutes later equivalent to 235 t of TNT. Approximately 50% of the buildings in the nearby town of Henderson, Nevada were destroyed, at cost of US$70 million. A natural gas pipeline that ran under the plant was ruptured in the event and burned for one week.

DATE OF LOSS	EVENT TYPE	SITE TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ADJ PROPERTY US$ MILLION
02/14/1989	EXPLOSION, FIRE	CHEMICAL	UERDINGEN GERMANY	63	141

Overheating and explosion of a reactor occurred, likely as a result of a runaway reaction. The cause was suspected to be the addition of the incorrect component. A neighboring building also was destroyed.

03/07/1989	EXPLOSION, FIRE	CHEMICAL	ANTWERP BELGIUM	79	178

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 this gas processing plant. As a result of this crack, which was caused by low cycle fatigue, ethylene oxide escaped near the level indicator and formed 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 completely destroyed the distillation section of this plant. The large resulting fire and impact of flying debris to other process sections resulted in extensive damage throughout the plant.

10/23/1989	EXPLOSION, VCE	CHEMICAL	PASADENA, TEXAS US	675	1,518

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 one minute after the release. The explosion had the strength of a 3.5 magnitude on the Richter scale earthquake.

The explosion destroyed two HDPE units, which included a total of eight particle form, loop reactor trains. The heat from the explosion caused BLEVEs of nearby pressurized storage tanks. Other process units at this chemical complex sustained only minor damage and resumed normal production within a few weeks of the incident.

The initial release of ethylene and isobutane occurred through an eight-inch-diameter ball valve 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 yet begun because of changes in priorities.

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.

03/11/1991	EXPLOSION, FIRE	CHEMICAL	PAJARITOS, COATZACOALCOS MEXICO	97	208

A gas leak involving the pipe rack that runs to the terminal of this petrochemical complex led to an explosion, which 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. These explosions and a subsequent fire completely destroyed the chemical plant, caused significant damage to the pipe rack, and resulted in moderate damage to other complex buildings and adjacent third-party facilities. The fire was extinguished after approximately three hours. Because of this incident, the chemical plant at this complex was completely shut down for seven months to allow for the rebuild of the plant and the pipe rack.

DATE OF LOSS	EVENT TYPE	SITE TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ADJ PROPERTY US$ MILLION
03/12/1991	EXPLOSION, FIRE	CHEMICAL	SEADRIFT, TEXAS US	90	194

An explosion occurred in the ethylene oxide process unit at this plant. As a result, 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 which contained methane and other hydrocarbon products. The subsequent fire that resulted from the released products was the only significant fire to occur during this incident.

As a result of the explosion, all utilities at the plant were lost for approximately one week. Additionally, several fixed fire protection systems were damaged by the explosion or inadvertently actuated due to a loss of plant air. These systems were shut off, 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.

05/01/1991	EXPLOSION, FIRE	CHEMICAL	STERLINGTON, LOUISIANA US	120	257

Workers were preparing to check a compressor in the nitroparaffin unit when they noticed a small fire and sounded the plant fire alarm. About 30 seconds later, an explosion occurred, which was followed by a series of smaller explosions. The effects of the initial explosion were reported as far away as eight miles from the plant. Additionally, the initial explosion completely damaged an area of the plant approximately 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.

05/27/1994	EXPLOSION	CHEMICAL	BELPRE, OHIO US	182	363

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

The fire then spread to involve part of the tank farm, resulting in the destruction of five atmospheric storage tanks. At approximately 12:30, the first of four one million US gallon and a 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.

10/20/1994	MECHANICAL DAMAGE, PRODUCTION LOSS	CHEMICAL	CEDAR BAYOU, TEXAS US	130	259

The Texas floods along the San Jacinto River shutdown the site, involving 650,000 tons-per-year ethylene, 200,000 tons-per-year linear low-density polyethene (LLDPE), 280,000 tons-per-year low-density polyethene (LDPE) plants, and general utilities. The loss of utilities affected further downstream clients. Flood water breached dikes around the main substation and inundated control rooms and offices.

12/13/1994	EXPLOSION	FERTILIZER	PORT NEAL, IOWA US	203	404

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

Metal fragments from the explosion punctured one of the plant's two 15,000-metric-ton refrigerated ammonia storage tanks. The punctured tank released an estimated 5,700 metric 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 metric 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.

06/22/1997	EXPLOSION	CHEMICAL	DEER PARK, TEXAS US	135	250

An explosion and large fire occurred in the olefins plant Number III at a petrochemical plant. The explosion was felt and heard more than 10 miles away and the ensuing fire burned for approximately 10 hours. The explosion and fire resulted in extensive damage to the facility and several workers received minor injuries. In addition, nearby properties were 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.

DATE OF LOSS	EVENT TYPE	SITE TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ADJ PROPERTY US$ MILLION
09/21/2001	EXPLOSION	CHEMICALS	TOULOUSE FRANCE	430	732

An explosion at this fertilizer plant killed 31 people and hospitalized more than 600. The blast shattered windows and ripped doors from their hinges in the center of the city three kilometers away. Two chimneys and several buildings at the factory were flattened and damage was caused to more than 3000 homes, 500 of which are reported uninhabitable. There was a secondary blast at a nearby explosives factory, said to be caused from sparks created by the first explosion. The thick red and yellow flumes that spread over the city were first thought to be toxic and the public were advised to remain indoors. The blast left a crater 50 meters in diameter and 15 meters deep.

04/23/2004	EXPLOSION	CHEMICAL	ILLIOPOLIS, ILLINOIS US	150	220

Five people were killed and two seriously injured following an explosion at a plastics plant producing 200 million barrels per year of specialty grade PVC. 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. The explosion was felt eight kilometers away. The highway was shut and local residents evacuated.

12/10/2005	EXPLOSION	CHEMICAL	MUNCHMUSTER GERMANY	200	280

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

04/29/2006	EXPLOSION	CHEMICAL	PORT ARTHUR, TEXAS US	200	268

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 shutdown of the facility for approximately six months, but caused no deaths or serious injuries.

03/20/2007	EXPLOSION	CHEMICAL	NIIGATA JAPAN	240	306

An accident occurred at a methylcellulose manufacturing facility. An explosion occurred and was followed by a fire, which was extinguished about seven hours later. A total of 17 people working at the site were injured in this accident; three critically, five seriously, and nine with minor injuries. There was one minor injury off site. Ignition of the methylcellulose powder is though to have been due to static electricity, resulting in a powder dust explosion. All methylcellulose operations were suspended for two months before sequentially restarting.

05/05/2012	EXPLOSION	CHEMICAL	MAP TA PHUT THAILAND	143	156

At least 12 people were killed and 129 injured in an explosion and fire at a petrochemicals plant that manufactured polybutadiene. In addition, thousands of people were evacuated from adjacent factories and communities within a three-kilometer-radius of the site. The explosion and subsequent fire sent thick black smoke into the air above the site. The deaths and injuries were as a result of blast injuries, burns, and inhalation of toxic fumes. It was reported that the explosion and fire occurred while workers were cleaning the polymer production line to change between batches, using toluene as a cleaning solvent.

12/22/2012	FIRE	CHEMICAL	LAVERA FRANCE	250	273

The incident occurred as a two-train, ethylene cracker was being started up after its major six-year turnaround. A spanner was left in the pipework going to the medium pressure stage of a compressor. This resulted in the compressor tripping on high vibration. The trip caused an overpressure in the high pressure stage of the compressor and a loss of containment of hydrocarbon that was ignited.

08/13/2015	EXPLOSION	CHEMICAL	LITVINOV CZECH REPUBLIC	180	187

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 the 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 10 cracker furnaces.

01/30/2017	FIRE	CHEMICAL	PORI FINLAND	180	267

A fire occurred at a titanium dioxide manufacturing facility, resulting in significant damage to the plant and the halting of production of the pigment until repairs could be completed.

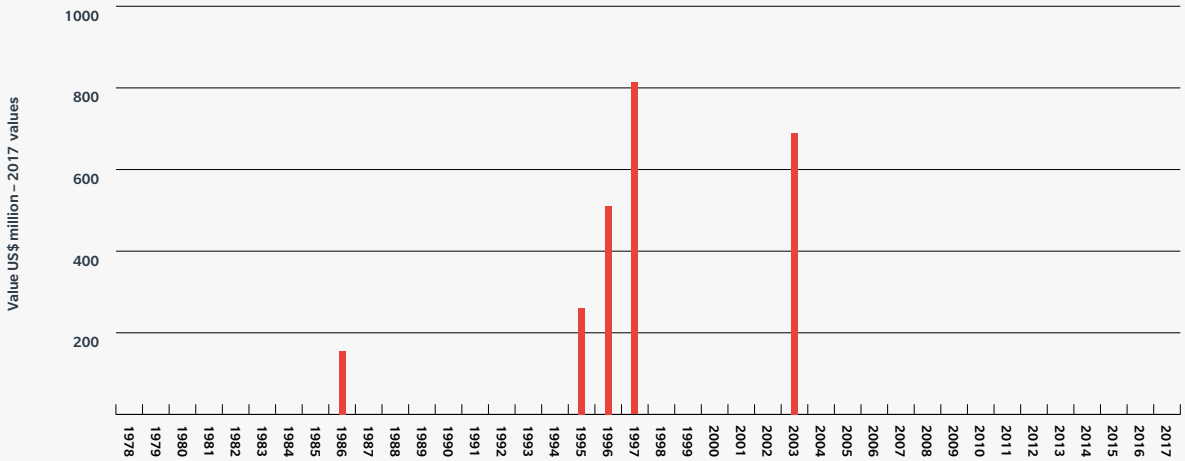
GAS PROCESSING

There are few gas processing industry losses identified in the 100 Largest Losses.

The gas processing sector continues to see major investment with the growth of the liquefied natural gas (LNG) industry, with many projects for liquefaction and gasification projects now operating globally.

The properties of LNG mean that the risk of internal corrosion is virtually eliminated. There is now excellent global experience with the design, construction, and operation of LNG facilities that has resulted in a very good loss history for the industry. However, the potential remains for high-consequence losses at facilities of this type, due to their complexity and value.

FIGURE 10 GAS PROCESSING PROPERTY DAMAGE BY YEAR
Source: Marsh Research



DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ADJ PROPERTY US$ MILLION
08/15/1987	EXPLOSION, VCE	JUAYMAH SAUDI ARABIA	65	156

At this gas processing plant, a series of electrical power interruptions caused several shutdowns of one or both of the identical 165,000 bbl-per-day gas fractionation process trains. The parallel trains were separated from one another by approximately 100 feet. At the time of the loss, the propane feed was approximately 100% of design capacity for Plant I and 25% of design capacity for Plant II.

It is believed that there was a release of approximately 1,900 bbl of propane in Plant I over a 30-minute period. A large vapor cloud is believed to have been ignited by a security vehicle, which had stalled and was being restarted. The probable source of the propane was a flange in a four-inch-diameter relief valve line.

07/26/1996	EXPLOSION	CACTUS, REFORMA, CHIAPAS MEXICO	137	260

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. As a result of the explosions, the Cryogenic Unit No. 2 and liquid petroleum gas (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. Consequently, plant personnel 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 this 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 was 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. If these spheres had failed due to BLEVE, the property plant damage would have been substantially greater. 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-cubic-feet-per-year gas-processing capacity at this complex was shut down, disrupting one third of Mexico's total gas-processing capacity.

12/25/1997	EXPLOSION	BINTULU, SARAWAK MALAYSIA	275	510

An explosion and fire occurred at a gas-to-liquids (GTL) plant in Bintulu, Sarawak. The fire was brought under control on 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-per-day 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.

09/25/1998	EXPLOSION, VCE	LONGFORD, VICTORIA AUSTRALIA	443	813

Gas supplies to Australia's Victoria State were virtually shut down following an explosion and fire at this gas processing plant. The specific 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 allowed some vessels to be chilled by cold oil, and when the hot oil was re-introduced to the heat exchanger, the vessel ruptured due to a brittle fracture. An initial release of approximately 22,000 pounds of hydrocarbon vapor exploded, and an estimated 26,000 pounds burned as a jet fire. The fire burned for two and a half days. Operator error and improper training of employees was sited in the report issued by the Longford Royal Commission formed to study the incident. One of the pipes at the plant had sprung a leak and ignited, with the heat bursting other pipes. Five explosions ripped through the gas plant, and, in addition to the 120 workers evacuated from the site, police evacuated houses within a five kilometer radius of the gas plant. The plant has a daily production capacity of 200,000 barrels per day of stabilized crude oil, 40,000 barrels per day of raw LPG, and 450,000 million cubic-feet-per-day of gas to supply natural gas customers. The gas outage has affected 1.4 million users statewide and forced small and large businesses to temporarily shut down. The estimated insurance payout is US$590 million. It is estimated that the shutdown cost industry nationally up to US$745 million in lost production.

01/19/2004	EXPLOSION	SKIKDA ALGERIA	470	689

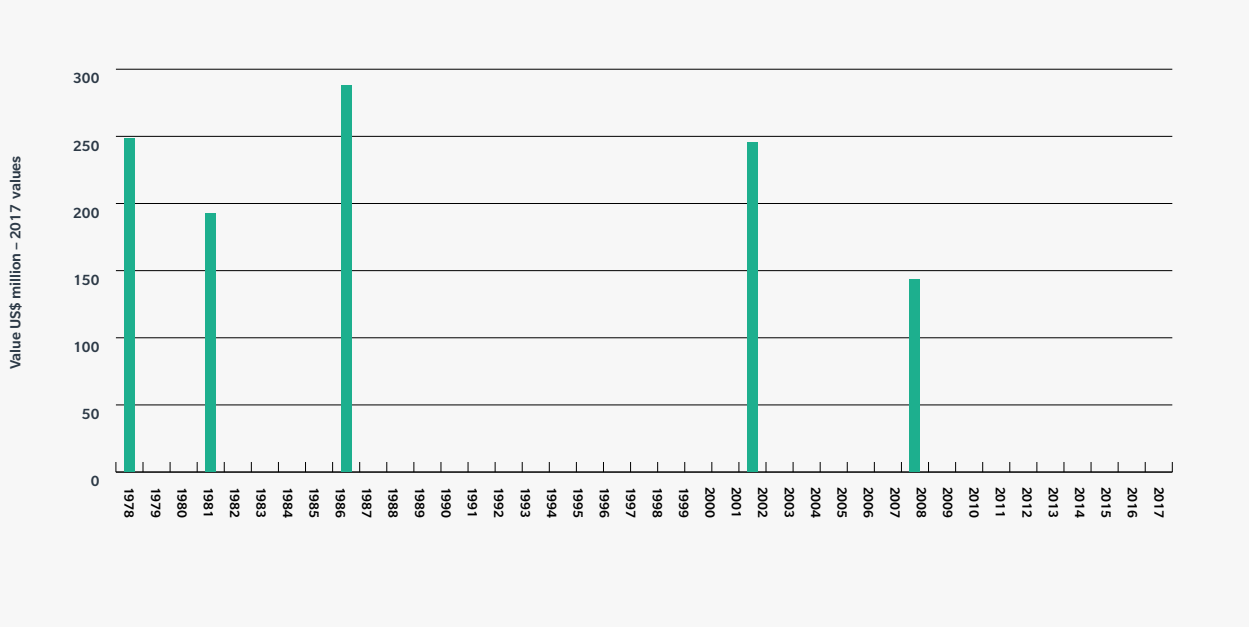
An explosion at a liquefied natural gas (LNG) plant resulted in 27 people killed, 72 injured, and seven reported missing. The explosion destroyed three out of six liquefaction trains, damaged a nearby power plant, and led to the shutdown of a 335,000 bbl per day refinery. There was also some damage to the neighboring 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 six of the LNG complex re-started in May 2004 and trains five and 10 in September 2004. Trains 20, 30, and 40 were destroyed in the incident, representing 50% of the capacity of the LNG complex.

TERMINALS AND DISTRIBUTION

Over the 40-year period under review, there have been only a few major losses associated with terminal and distribution operations that resulted in major property damage. This reflects the low-value concentration associated with pipelines, storage, and distribution terminals. Although terminals can be high-value locations, they are typically large and spread out, with a single event rarely impacting more than a small part of the site.

There have been several major terminal losses over recent years in the UK, India, and Puerto Rico – these losses tend to be spectacular, and therefore well-publicized. Although all of these were significant, and have been important for learning lessons to improve process safety performance, the property damage associated with these losses was relatively low.

FIGURE 11 TERMINALS AND DISTRIBUTION PROPERTY DAMAGE LOSSES BY YEAR
Source: Marsh Research



DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ADJ PROPERTY US$ MILLION
01/08/1979	EXPLOSION	BANTRY BAY IRELAND	70	248

An 11-year-old, 121,000-deadweight-ton tanker had completed unloading its first parcel of Arabian heavy crude when a small fire was noticed on deck. About 10 minutes later, fire spread to both sides of the ship. Later, a massive explosion occurred. The initiating event of the disaster was likely the buckling of the ship's structure at deck level. Explosions in the ballast tanks and the breaking of the ship's back followed. These events were produced by the conjunction of two separate factors: a seriously weakened hull due to inadequate maintenance and an excessive stress due to incorrect ballasting at the time of the disaster. In addition to the total loss of the ship, 1,130 feet of the concrete and steel jetty were damaged or destroyed.

12/19/1982	FIRE	TACOA VENEZUELA	70	193

A huge boil-over occurred on a fuel oil tank, killing at least 160 people in a huge fire ball. The explosion occurred on the fuel oil tank while it was being gauged, blowing the roof off the tank and setting it on fire. Eight hours after the tank fire started a violent boil-over occurred. Burning oil flowed down the hill where the tank was located and surrounded a second tank.

03/05/1987	EARTHQUAKE	ECUADOR	120	288

Some 25 miles of Trans-Andean pipeline disappeared in this 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 was a total of 10 earthquakes in total. Repairs took several months.

01/31/2002	EXPLOSION	RAUDHATAIN KUWAIT	150	246

Four people were killed in an explosion and fire at an 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 the adjacent gas booster station. At least 19 people were injured in the incident, mainly suffering first- and second-degree burns. The fire was extinguished two days after the event.

06/03/2008	EXPLOSION	VARANUS ISLAND AUSTRALIA	120	143

A gas release from a corroded pipeline resulted in an explosion at a gas plant. This resulted in a 30% reduction in the Australian state's domestic gas supply and a 45% reduction in the supply of gas to mines and other industries. Workers were evacuated from the island as a precaution. It took six months before the plant was returned to full capacity operation.

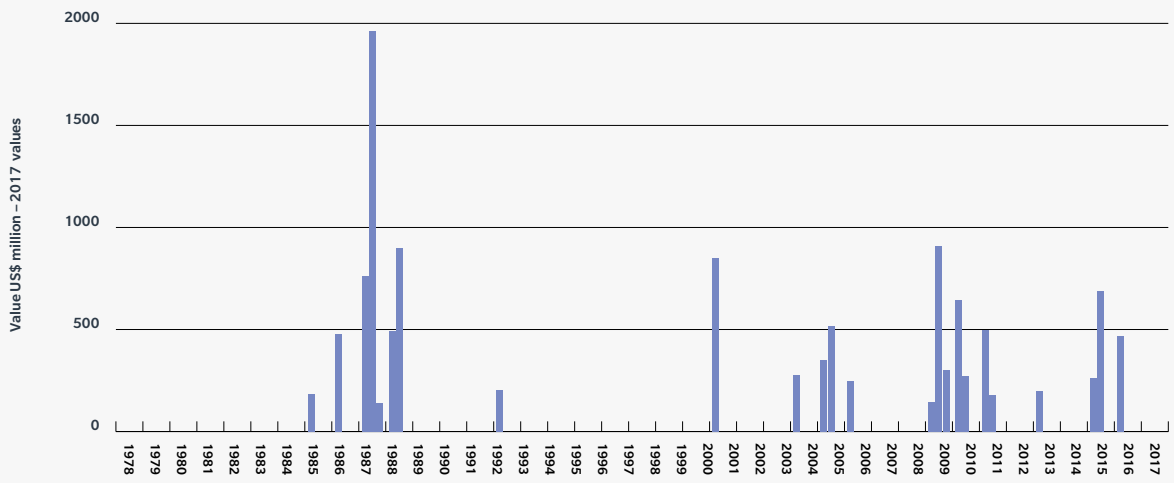
UPSTREAM

There continue to be significant upstream losses, including one in the past two years as a result of a mechanical failure on a floating production, storage, and loading vessel, which resulted in significant interruption to the oil production from the field.

The Piper Alpha disaster 30 years ago in the UK North Sea continues to be the largest recorded offshore property damage loss. Meanwhile, the Deepwater Horizon loss in 2010 had major third-party liability impact, as a result of the loss of well control and the massive release of crude oil into the Gulf of Mexico.

We continue to see the evolution of the upstream industry with increasing fracking activity in more countries. The potential capacity of supply from fracked oil and gas is enormous, but the assets are generally of relatively small size and are well dispersed. Therefore, although losses have occurred in the industry, none individually is very large.

FIGURE 12 UPSTREAM PROPERTY DAMAGE LOSSES BY YEAR
Source: Marsh Research



DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ADJ PROPERTY US$ MILLION
08/26/1986	MECHANICAL DAMAGE	SEA OF JAPAN JAPAN	75	185

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

11/04/1987	BLOWOUT	BOURBON FIELD, WELL A17, GULF OF MEXICO US	200	479

Sustained casing head pressure leaked from the production casing into the outer casing strings, resulting in the failure of one of the casing strings. This caused an underground blowout that resulted in extensive damage to the platform and a gas plume around the platform. The well was killed to stabilize conditions on the seabed.

04/24/1988	BLOWOUT	ENCHOVA, CAMPOS BASIN BRAZIL	330	762

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 business operations platform (BOP) 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. The majority 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 the loss of production as much as possible. Full production was restored 18 months after the loss.

07/ 06/1988	EXPLOSION	PIPER ALPHA, NORTH SEA UNITED KINGDOM	850	1963

A release and ignition of gas condensate from a section of piping in the gas compression module of this platform set off a chain of fires and explosions, resulting in the almost total destruction of the facility. 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 largely due 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, which was rendered useless by the initial explosion.

In addition, the firewater pumps had been placed in to manual operation mode due to divers being in the water prior to 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, which was directly over the site of the initial release and resulting explosion and fire.

12/24/1988	MECHANICAL DAMAGE	FULMAR FIELD, NORTH SEA UK	60	138

Failure of seabed components caused 210,000 metric tonnes of FSU to break free in bad weather. Three out of four latch plates fractured. About 210,000 bbl-per-day of crude was lost, equating to about 10% of UK production.

01/20/1989	PRODUCTION LOSS	TREASURE SAGA, NORTH SEA NORWAY	220	495

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. It was stabilized after 11 months by pumping heavy mud down a relief well and was later sealed.

03/19/1989	EXPLOSION, FIRE	BAKER, GULF OF MEXICO US	400	899

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 total destruction of the platform and seven fatalities. It took two years to replace the platform.

03/25/1993	EXPLOSION, VCE	LAMA, LAKE MARACAIBO VENEZUELA	100	194

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. There were 11 fatalities.

DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ADJ PROPERTY US$ MILLION
03/15/2001	EXPLOSION	RONCADOR FIELD, CAMPOS BASIN BRAZIL	500	851

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 metric tons of seawater to keep the rig afloat, but were unsuccessful. On March 20, 2001, the rig sank to the sea floor. The incident killed 11 workers.

08/10/2004	BLOWOUT	TEMSAH EGYPT	190	279

A fire broke out during drilling operations at an offshore gas production platform following a well control incident. The fire on the production platform, initially under control, 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 people 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.

07/10/2005	MECHANICAL DAMAGE	THUNDERHORSE, GULF OF MEXICO US	250	350

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 seabed production equipment after a series of tests revealed metallurgical failure in components of the field subsea systems.

07/27/2005	EXPLOSION, FIRE	MUMBAI, HIGH NORTH INDIA	370	518

A total of 22 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 a further 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. Some 73 people were evacuated from the rig however, one employee died during the evacuation. Meanwhile, six divers in a saturation chamber on the vessel were rescued 36 hours later.

11/05/2006	RELEASE	NORTH SEA NORWAY	185	248

Offshore gas alarms were triggered on this floating production unit. 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.

01/26/2009	MECHANICAL DAMAGE	OFFSHORE ANGOLA	120	145

An anchor-handling tug operating around an offshore field lost control and drifted over a subsea center. The anchor wires snagged the subsea equipment, causing damage to a Christmas tree, well conductor, and subsea control module. The remedial actions required included the plugging and abandonment of one well and the drilling of a replacement well.

DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ADJ PROPERTY US$ MILLION
06/04/2009	PRODUCTION LOSS	NORTH SEA NORWAY	750	909

A well-intervention vessel lost power and collided with an unmanned platform forming part of this 230,000 bbl per day complex. Heavy damage was caused to the vessel and the platform, including damage to the platform structure, linking access bridge, and well equipment. Some 23,000 bbl per day 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 catalog of further damage from the collision also identified.

08/21/2009	RELEASE	TIMOR SEA AUSTRALIA	250	303

Oil, condensate, and hydrogen sulphide leaked from a wellhead on platform being serviced by a jack-up rig in the Timor Sea. A total of 69 workers on the rig were evacuated. Oil and gas started spilling after a plug blocking one of the project's 1,200-meter deep wells came free. The next day, a 12-kilometer-long, 30-meter-wide spill was reported. Attempts were made to plug the well over the next two months. It was estimated that the well was leaking 400 bbl-per-day of oil and gas. On November 1, 2009, 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 deeper leak was being plugged. The fire was extinguished two days later. A total of about 4,140 tons of oil was estimated to have been lost. The incident affected both the platform and the drilling rig.

04/21/2010	EXPLOSION, FIRE	GULF OF MEXICO US	560	644

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 crew of 126, and 11 people were immediately identified missing and subsequently confirmed as fatalities, with a further 17 people injured. The rig sank within 36 hours of the initial explosion in a water depth of approximately 5,000 feet. The exploration well had reached a depth of 18,360 feet (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 blow-out preventer (BOP) for a 87 days before successful static kill, causing a spill of national significance and an unprecedented subsea and surface spill control response. The well was declared finally killed five months after the original event by successful interception by a relief well.

05/13/2010	SINKING	CARIBBEAN SEA VENEZUELA	235	270

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 subsea safety valves meant the well was secure and no leakage of oil occurred.

02/04/2011	PRODUCTION LOSS	NORTH SEA UNITED KINGDOM	450	497

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, however, this infrastructure was damaged in the incident.

Following the vessel moving off its position, all of the wells were immediately shut in. Subsequent surveys showed that no oil had been lost. The 74 non-essential crew were evacuated to near-by platforms and 43 essential crew members remained onboard. Two members of crew received minor injuries. The facility was projected to be producing an average of 18,400 bbl-per-day of oil prior to the loss.

04/12/2011	SINKING	GULF OF MEXICO MEXICO	160	177

A total of 638 workers were evacuated from this flotel after it began to lean to one side when water entered a pontoon. The flotel was located about 80 kilometers offshore Campeche, Mexico. There were no injuries reported as a result of the sudden inclination. It was reported that a total loss of the flotel resulted.

DATE OF LOSS	EVENT TYPE	LOCATION COUNTRY	PROPERTY DAMAGE US$ MILLION	ADJ PROPERTY US$ MILLION
07/01/2013	MECHANICAL DAMAGE	ATLANTIC OCEAN ANGOLA	182	197

A jack-up sank after the seabed collapsed under one of its three legs. The rig sank while being positioned for drilling operations in approximately 40 meters of water. Some 103 workers were onboard the rig when it suddenly tilted, causing the rig to take on water and capsize. One crew member went missing and six others received minor injuries.

03/11/2015	EXPLOSION	CAMARUPIM FIELD BRAZIL	250	264

An explosion on a FPSO off the coast of Brazil resulted in nine fatalities and multiple wounded. The accident happened as the vessel was anchored in the Atlantic Ocean 120 kilometers from the coast of Espirito Santos, Brazil. The FPSO is a converted very large crude oil tanker (VLCC), 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. The majority of fatalities were believed to be part of the emergency response team. FPSO took on water, but the explosion did not result in a breach of the hull of the vessel.

04/01/2015	FIRE	BAY OF CAMPECHE MEXICO	500	650

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 the cause of the initial failure.

02/11/2016	MECHANICAL DAMAGE	JUBILEE FIELD GHANA	450	466

The main turret bearing on a FPSO 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 deepwater offloading buoy.

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