MARSH

Property Risk Consulting

The 100 Largest Losses 1972-2001

Large Property Damage Losses in the Hydrocarbon-Chemical Industries.

20th Edition: February 2003
A Publication of
Marsh's Risk Consulting Practice

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James C. Coco - Editor

Acknowledgement

Marsh's Risk Consulting practice acknowledges the significant input from various sources interested in the prevention, mitigation, and analysis of large property damage losses that make this publication possible. We will continue to rely on information provided from interested professionals as well as published sources, and to encourage readers to bring errors, omissions, or additional information to our attention.

Additional copies of this publication are available through the worldwide offices of Marsh's Risk Consulting practice.

Cover photo courtesy of the Agence France-Presse (AFP)

Foreword

This twentieth edition of **Large Property Damage Losses**, a publication of Marsh's Risk Consulting practice, is dedicated to all those lost as a result of the attacks of September 11, 2001. In particular, we dedicate this issue to:

- Our 295 colleagues lost in the attack on the World Trade Center. We miss them and will remember them always.

- The 403 emergency responders from the Fire Department of the City of New York, New York City Police Department and the New York/New Jersey Port Authority Police Department who lost their lives coming to the aid of our colleagues and others. Their dedication, professionalism, and bravery leave us in awe.

Harry Taback was one of our Marsh colleagues lost. Harry's vision, guidance, and support made this and the previous 19 editions of this publication possible.

Introduction

Twentieth Edition

James C. Coco, PE, CSP
Editor

Our twentieth edition reviews the 100 largest property damage losses that have occurred in the hydrocarbon-chemical industries over the last 30 years. This review used our Energy Losses Database as well as information available from several other sources. The Energy Losses Database contains approximately 5,400 records for the 30-year period from 1972 through 2001. We have limited our analysis to losses of $10,000,000 or greater since many hydrocarbon processing companies have a property damage insurance deductible in that range. We have also provided a separate listing of all the losses in the 30-year period analyzed that exceeded $150,000,000 in property damage.

Although nearly all of the losses involved fires or explosions, many have occurred as the direct result of floods, windstorm, and pressure vessel rupture related events. Marine transportation losses are excluded, except for those involving marine vessels moored at plant docks.

The large property damage losses have been grouped by type of facility into five categories: Refineries, Petrochemical Plants, Gas Processing Plants, Terminals/Distribution, and Offshore. The 100 largest losses analyzed in this edition are limited to onshore losses for consistency with previous editions of the publication, and represent approximately $10,800,000,000 in property damage, stated in January 2002 dollars. Offshore losses are considered separately and represent approximately $3,800,000,000 in property damage in January 2002 dollars. The loss amounts were trended using an inflation cost index for petroleum equipment, thus allowing for a comparison of events on a constant dollar basis over the 30-year period. Based on available data, we attempt to state dollar losses on the basis of cost to repair or replace assets damaged or destroyed.

The loss amounts include property damage, debris removal, and cleanup costs while the costs of business interruption, extra expense, employee injuries and fatalities, and liability claims are excluded. The direct, on-premises cleanup costs due to asbestos abatement, PCB removal, or released hydrocarbons and chemicals following a fire, explosion, or other loss event have traditionally

been considered part of the property damage loss. These costs, to the extent insurance is applicable, are paid by property insurance underwriters.

As shown by the bar charts in the introductions to each of the five facility categories, the number of losses over five-year intervals from 1987, regardless of dollar amount, have continued to rise. The only exception to this trend is the number of petrochemical losses outside the U.S. in the five-year period of 1997 to 2001 that showed a decrease in the number of losses. Contributing factors to the increase in the number of losses, both in the U.S. and worldwide, include continued aging of facilities, failure to follow procedures, cutbacks in personnel, budget restraints, and changing regulatory requirements. The offshore statistical information relied on the most recent data from the U.S. Minerals Management Service (MMS).

Introduction

A Specialized Global Practice

U.S. Marine & Energy Headquarters Moves to Houston

William P. Martin
President
Marsh's U.S. Marine & Energy practice

In its continuing commitment to the specialized investment required to bring advanced risk solutions to the marine and energy industries, Marsh announced the move of its U.S. Marine & Energy practice headquarters from New York to Houston at the end of the first quarter of 2002. This move does not mean that the size and structure of the very successful New York operation will be reduced in any way. New York will retain its large energy operation as well as its lead role in the blue water marine business. The primary change is that there will be significant expansion of specialty resources in the Houston office to focus on the full spectrum of energy operations.

While the Houston office already had a large energy department handling some of the nation's largest E&P and petrochemical operations, the headquarters move acknowledges that Houston is the global center of the energy industry and requires a special investment strategy going forward. We are changing our organizational profile to match our clients' operational profile, which is already global in scope. In this regard, the U.S. Marine & Energy operations will report directly to Marsh's Global Marine & Energy practice in London, which is headed by the Marine & Energy Chairman, John J. Lapsley. This facilitates a "wherever/whenever" service and solutions strategy for Marsh clients. Whether clients are investing in operations in the Caspian, Vietnam, West Africa, or Middle East, Marsh's Marine & Energy practice can respond with comprehensive service and solutions.

Taking a closer look at Houston; *specialization* is the theme:

Broking Specialization

The energy technical broking staff has been increased in size with specialized groups in offshore, onshore energy and energy casualty. These broking groups link directly to a similar structure in the New York office energy group for optimum market intelligence and leverage.

Industry Segments

Client executives and service teams are focused on various industry groups which include integrated oils, E&P, refining and petrochemical, and oil field service to bring real understanding of the client's business to customized solutions.

Loss Control and Claims

Marsh's U.S. Marine & Energy practice has not limited its investment to the risk transfer transaction; the number of loss control engineers and claims specialists has also been increased. Whether

it's property, casualty or control of well issues, the practice has experts to address them.

International

International energy experts have been added to the team. These individuals have language skills to facilitate client activities in West Africa and other locations.

Energy Financial & Operational Risk

Finally, Marsh's U.S. Marine & Energy practice has invested in energy banking, and financial expertise to drive financial/insurance structured solutions. From an operating risk perspective, a close working relationship has been established with Mercer Management Consulting's Global Oil & Gas Chemicals practice, also located in Houston. A team approach with this group brings energy specific ERM capabilities to the energy industry. This capability will play a critical role as insurance markets shift more risk to the industry in a hardening insurance environment.

In conclusion, the headquarters transition will be a real benefit for our clients. It brings them a true global practice with unmatched depth of resources in one of the world's capitals of the energy industry. It really represents a commitment to partner with our clients to facilitate their business and control their total cost of risk wherever they operate in the world.

Largest Property Damage Losses 1972 to 2001

(Excess of $150,000,000 property damage)

Onshore

Date	Location	Plant Type	Event Type	PD Loss ($MM)
10-23-89	Texas	Petrochemical	VCE*	839
9-1-01	France	Chemical	Explosion	750
6-24-00	Kuwait	Refinery	Explosion	412
5-4-88	Nevada	Chemical	Explosion	383
5-5-88	Louisiana	Refinery	VCE	368
9-27-98	Mississippi	Refinery	Hurricane	340
11-14-87	Texas	Petrochemical	VCE	285
12-25-97	Malaysia	Gas Plant	Explosion	282
7-23-84	Illinois	Refinery	VCE	268
11-9-92	France	Refinery	VCE	262
12-13-94	Iowa	Chemical	Explosion	224
9-18-89	Virgin Islands	Refinery	Hurricane	207
8-17-99	Turkey	Refinery	Earthquake	200
5-27-94	Ohio	Chemical	Explosion	200
9-25-98	Australia	Gas Plant	Explosion	200
7-23-84	Illinois	Refinery	Explosion	191
10-16-92	Japan	Refinery	Explosion	187
3-4-77	Qatar	Gas Plant	VCE	174

*VCE: Vapor Cloud Explosion

This listing does not include the onshore losses to the Kuwait oil fields during the Gulf War. Total losses are estimated at $2,546,000,000 (US).

Largest Property Damage Losses
1972 to 2001
(Excess of $150,000,000 property damage)

Offshore

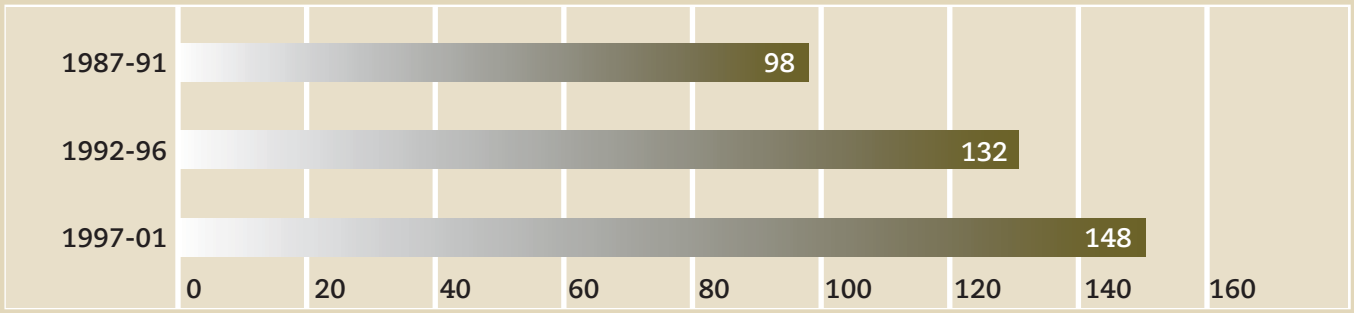
Date	Location	Facility Type	Event Type	PD Loss ($MM)
7-7-88	North Sea	Platform	Explosion	1,085
8-26-92	Gulf of Mexico	Platforms	Hurricane	931
3-15-01	Brazil	Platform	Explosion/Fire	500
8-23-91	North Sea	Concrete Jacket	MD*	474
4-24-88	Brazil	Platform	Blowout	421
11-1-92	Australia	Jacket	MD	314
1-20-89	North Sea	Drilling	Blowout	273
11-2-99	Indonesia	Process Deck	MD	210
7-1-75	Dubai	Platform	Blowout	204
11-04-87	Gulf of Mexico	Platform	Blowout	200
10-1-74	North Sea	Platform	MD	196

*MD: Mechanical Damage

Refineries

Losses in the refinery industry have continued to increase over the last few years and the causes highlight the aging facilities in this category. A significant number of larger losses (over $10,000,000) have been caused by piping failures or piping leaks, leading to fires and/or explosions. Several large losses due to piping failures were due to corrosion issues or using the wrong metallurgy. Weather-related incidents played a major role in two losses that were each over $200,000,000. Incidents occurring during startup or shutdown continue to cause significant dollar losses. Total losses for the refinery incidents contained here, in January 2002 U.S. dollars, is approximately $5,000,000,000.

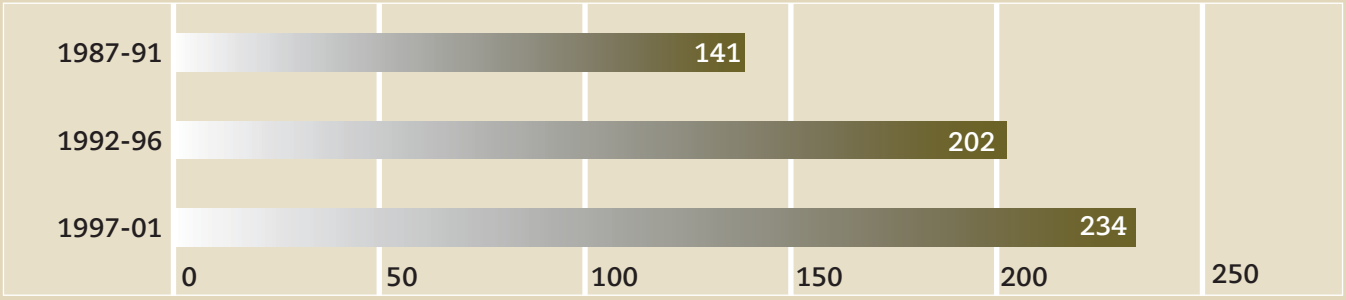
Refinery Losses in 5-Year Intervals U.S.



The above chart highlights the continued increase in the number of losses in the U.S. Refinery category. A somewhat positive sign is that the percentage increase over the last 5-year interval (1997-2001) is significantly less than the percentage increase over the previous intervals.

Refineries

Refinery Losses in 5-Year Intervals **Outside U.S.**



Refinery losses outside the U.S. have also continued to increase. However, as with the U.S. refinery losses, the percentage increase has been reduced significantly.

A fire in the hydrocracking unit damaged the unicracker. Cause of the fire was attributed to established procedures not being followed. The fire took 19 hours to extinguish. Three people were injured as a result of the incident.

Fire

September 21, 2001
Lake Charles, Louisiana, United States
$50,000,000 **$52,000,000**

The refinery, which produces 160,000 barrels of gasoline and distillates per day, was shut down due to a fire in the crude distillation unit. Three days later the distillation tower suffered a structural failure due to corrosion issues compounded by the fire. The crude unit was down for six months.

Fire

August 14, 2001
Lemont, Illinois, United States
$35,000,000 **$36,000,000**

A fire in the crude distillation unit caused a two-week shutdown of the unit. Cause of the fire was believed to be a pump seal failure. Firefighting efforts took 12 hours to extinguish the fire.

Fire

April 28, 2001
Wood River, Illinois, United States
$65,000,000 **$68,000,000**

A piping leak resulted in a fire in the refinery coker unit. Smoke rose to over 3,000 feet, and the coker was shut down for approximately two months. The exact cause of the incident is under investigation.

Fire

April 23, 2001
Carson City, California, United States
$120,000,000 **$124,000,000**

An explosion and fire occurred in the saturate gas plant causing severe damage to this area and a heater serving part of the coker unit of this refinery. Due to a bank holiday, only minimum staff were on site at the time of the explosion. The plant fire brigade was responsible for isolating the escaping gas preventing further damage. The fire following the explosion was brought under control in about two hours by the plant and local fire brigades.

Fire/Explosion

April 16, 2001
Killingholme, United Kingdom
$80,000,000 **$82,400,000**

An oil spill occurred due to a failure of a block valve to seat properly during maintenance on a pump strainer in the Visbraker unit. The oil auto-ignited and the ensuing fire spread and destroyed the Visbreaker and damaged adjacent equipment. Subsequent explosions and heat restricted firefighting access, and 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 extinguished with the help of the local fire department.

Fire

April 9, 2001
Aruba
$130,000,000 **$134,000,000**

Refineries

Fire/Explosion

June 25, 2000
Mina Al-Ahmadi, Kuwait
$412,000,000 **$433,000,000**

The explosion occurred when employees were attempting to isolate a leak on a condensate line between the 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. Initial investigation into the loss indicates a lack of inspection and maintenance of the condensate line.

Explosion

December 2, 1999
Sri Racha, Thailand
$35,000,000 **$37,000,000**

The fire occurred when a storage tank was overfilled resulting in destruction of five gasoline storage tanks and 250,000 barrels of gasoline. Even though high-level alarms sounded, the tank continued to be filled due to the opening of the wrong valve. The fires burned for 35 hours. Foam was flown in from Singapore after local stocks were exhausted. The incident resulted in the death of 8 people and injury to 13 others. The personnel toll would have been much higher had the explosion not occurred at 11:30 pm.

Earthquake

August 17, 1999
Korfez, Turkey
$200,000,000 **$210,000,000**

An earthquake measuring 7.4 on the Richter scale caused a collapse of a 312-foot-high chimney setting off fires at this 226,000 barrels-per-day refinery. The fires 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 United States and many other countries sent foam supplies, personnel and equipment to fight the fires. Damage to the refinery included total loss of six storage tanks, four storage tanks deformed, 50 percent damage to floating roof tanks, and damage to the crude distillation unit, a reformer, and several connecting pipelines.

Explosion

March 25, 1999
Richmond, California, United States
$75,000,000 **$79,000,000**

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

A release and auto-ignition of light gas oil occurred due to a failure of an overhead line connecting a crude furnace to a reactor in the crude distillation unit. The pipe failure was attributed to the pipe being the wrong metallurgy for the service. The fire took three hours to extinguish.

Fire/Explosion

February 19, 1999
Thessaloniki, Greece
$40,000,000 **$43,000,000**

The fire occurred when the plant was being brought down for a turnaround. The fire started when a gas oil line failed due to accelerated naphthenic acid corrosion and ignited when the material contacted a hot process line. This caused the failure of a kerosene air cooler, adding additional fuel to the fire. Affected units were a 127,000 barrels-per-day crude unit and a 17,000 barrels-per-day reformer.

Fire

October 6, 1998
Berre l'Etang, France
$22,000,000 **$23,000,000**

The entire refinery was shut down for three months after being struck by Hurricane Georges. The hurricane left the entire plant submerged by 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 that is located close to the shore of the Gulf of Mexico. In all 2,100 motors, 1,900 pumps, 8,000 instrument components, 280 turbines and some 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 5 feet above grade.

Hurricane

September 26, 1998
Pascagoula, Mississippi, United States
$340,000,000 **$357,000,000**

The fire originated as a result of an explosion in the hydrocracker. The crude processing rate was reduced until repairs could be made. One person was killed in the incident.

Fire/Explosion

June 9, 1998
St. John, New Brunswick, Canada
$61,500,000 **$66,000,000**

A pipeline carrying LPG from a harbor terminal to the refinery developed a leak. The LPG found an ignition source that triggered a large vapor cloud explosion. The resulting fire engulfed 18 storage tanks, destroying seven tanks containing LPG and crude oil. The explosion and fires resulted in the death of 50 people.

Explosion/Fire

September 14, 1997
Visakhapatam, India
$60,000,000 **$64,000,000**

Explosion/Fire

January 27, 1997
Martinez, California, United States
$80,000,000 **$22,000,000**

At 7:41 p.m. on January 27, an effluent line from a reactor in the hydrocracker unit failed, resulting in an explosion and fire. The line apparently ruptured due to excessively high temperatures, and the failure to depressurize the unit upon detection of high temperature. Seconds before the explosion, a section of the pipe was reported as glowing red. The hydrocarbons apparently auto-ignited shortly after the initial release.

Following the event, the rupture of the 12-inch effluent line was discovered on a straight run of pipe, not at a weld. Analysis of the failed section of pipe, at the point of failure, indicated that the pipe had expanded in circumference by approximately 5 inches. This caused a localized bulge in the pipe prior to rupture. Other sections of the reactor effluent piping had also expanded. This expansion is consistent with short-term creep of 1-1/4% chromium, 1/2% molydenum steel at temperatures above 1,300°F.

Explosion/Fire

October 24, 1995
Cilacap, Indonesia
$33,000,000 **$38,000,000**

A lightning strike to a floating roof storage tank containing naphtha resulted in the initial fire at this 302,000 barrels-per-day refinery. The fire then spread to involve six additional storage tanks containing various types of hydrocarbon products. As a result of this incident, three of the storage tanks involved were completely destroyed while the other four storage tanks involved were extensively to moderately damaged. Reportedly, one of the storage tanks was still on fire approximately 20 hours after the lightning strike occurred.

Because of this incident, the refinery was operating at approximately 70 percent of throughput capacity as of July 1996.

Fire

October 16, 1995
Rouseville, Pennsylvania, United States
$40,000,000 **$46,000,000**

A fire occurred at approximately 10 a.m. at this 15,700 barrels-per-day refinery. As a result, several pipe racks, two wastewater storage tanks, and several intermediate product storage tanks near process units in the center of the refinery were extensively damaged. The pipe racks were critical for refinery operations since they contained utility lines for process units in the north and south parts of the plant.

Because of this incident, the refinery was shut down for three months while repairs to the damaged pipe racks and storage tanks were completed. The business interruption loss associated with this incident is estimated at $14,000,000.

Fire

July 24, 1994
Pembroke, United Kingdom
$77,500,000 **$91,000,000**

A severe thunderstorm passed over the refinery between 7:20 a.m. and 9:00 a.m. on July 24. 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 column pressure safety valves lifting and major process unit upsets in other refinery units including those within the fluid catalytic cracking (FCC) complex. This 90,000 barrel-per-day cracking complex, which includes the FCC unit, Butamer unit, alkylation unit, and an idle hydrogen plant, was a joint venture of two refining companies.

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. Except for the FCC unit itself, all units in the cracking complex 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 became an explosive mixture that drifted within the process area prior to being ignited by a heater. The explosion, which occurred at 1:23 p.m., was centered in the process area approximately 360 feet (110 meters) from the FCC on-plot flare drum.

Following the explosion, a number of 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. The firefighting was handled by the refinery emergency services with assistance from the Dyfed County Fire Service.

As a result of this incident, an estimated 10 percent of the total refining capacity in the United Kingdom was lost until this complex was returned to service. The business interruption loss for this incident is estimated at $70,000,000, which reflects four and one-half months downtime.

Fire

February 25, 1994
Kawasaki, Japan
$35,000,000 **$41,000,000**

The mechanical failure of a flue gas turbine expander and subsequent fire originating in an 86,000 barrels-per-day FCC unit occurred at this 220,000 barrels-per-day refinery. As a result of this incident, the flue gas turbine expander on the FCC regenerator was completely destroyed while adjacent product pipe racks, a FCC heater, a vacuum unit heater, and process equipment on multilevel decks were significantly damaged.

Reportedly, control valve problems had developed with the position controller for the flue gas turbine expander, which generated electric power for the public utility grid using flue gas exhaust from the FCC regenerator. Refinery personnel were conducting on-line maintenance when the turbine expander went into an overspeed condition and subsequently failed. Metal fragments from the turbine expander failure damaged nearby process equipment and product pipe racks, including the puncture of several product lines. The hydrocarbon liquid released from the product lines was subsequently ignited, resulting in a fire.

Firefighters from the refinery fire brigade and local fire department worked for approximately eight hours using foam and cooling water hose streams to extinguish the fire. Additionally, the extensive use of remotely operated isolation valves by refinery personnel greatly limited the amount of hydrocarbon liquid released during the fire-fighting effort.

The refinery was shut down for approximately three months while the repairs to the damaged heaters, pipe racks, and process equipment were completed. Additionally, the destroyed flue gas turbine expander was not replaced. The business interruption loss associated with this incident is estimated at $40,000,000.

Fire

August 2, 1993
Baton Rouge, Louisiana, United States
$65,200,000 **$78,000,000**

Operations were normal at this 421,000 barrels-per-day refinery when a fire occurred at 4:21 a.m. in the central unit of three delayed coker units, which have throughput capacities of 32,000 barrels-per-day each. These units each consist of four 100-foot metal coke drums set about 40 feet above grade and topped with 100-foot drilling derricks.

Operators were in the process of switching feed from “D” drum to “C” drum and two contractors were preparing to cut the coke in “D” drum when a 45-degree elbow in the feed line ruptured, releasing hydrocarbon at the 40-foot level. This 6-inch diameter elbow was made of carbon steel instead of the 5 percent chrome alloy steel

required by the design specifications since some of the pipes in this unit area reach temperatures up to 900°F An investigation indicated that the piping on each side of the ruptured elbow, which was fabricated and installed in 1963, was of the proper alloy steel.

The sustained, intense fire caused other pipes in the unit area to rupture, releasing additional hydrocarbons and involving the entire structure in fire. As a result of the fire, two of the drilling derricks were completely destroyed and the two remaining derricks were partially damaged. There was also significant damage to the coke drums, electrical, instrumentation, and associated equipment in the central unit. Upon report of the fire, approximately 12 members of the refinery primary fire brigade arrived within minutes at the delayed coker unit. These brigade members were supplemented within 15 minutes by an additional 83 members from the refinery primary and volunteer fire brigades, and the fire brigade from an adjacent chemical plant. The Baton Rouge Fire Department went to the scene and was available to assist these fire brigades but did not actively fight the fire. These fire brigades battled an intense fire for nearly three hours until all sources of fuel were shut off. The small fires that continued to flare up in the unit were completely extinguished by 6:00 p.m.

Because of this incident the west coker unit was shut down for three weeks for testing while the east unit was shut down for a slightly longer period while investigators checked the piping in this unit for proper metals.

Vapor Cloud Explosion

November 9, 1992
La Mede, France
$260,000,000 **$318,000,000**

Operations were normal at this 136,000 barrels-per-day refinery when a vapor cloud explosion occurred in the gas plant associated with the 29,700 barrels-per-day FCC unit. The initial vapor cloud explosion and several subsequent lesser explosions could be heard in Marseilles, approximately 18 miles from the refinery. An estimated 11,000 pounds of light hydrocarbons were involved in the initial explosion.

At approximately 5:17 a.m., 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 at approximately 5:20 a.m. The initial gas release is believed to have resulted from a pipe rupture in the gas plant, which is 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. Two new process units under construction which were 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, with some broken windows up to six miles away.

The refinery fire brigade and over 250 firemen from three neighboring industrial sites and four nearby towns were utilized for more than six hours to bring this incident under control. Approximately 37,000 gallons of foam concentrate were used during the firefighting effort. Some fires were intentionally left burning after the incident was under control at 11:30 a.m. to allow safe depressurizing of the process units since the flare system was partially damaged by the explosions. All of the fires were extinguished by 5:30 p.m.

The business interruption loss associated with this incident is estimated at $180,000,000

Explosion/Fire

October 16, 1992
Sodegaura, Japan
$160,500,000 **$196,000,000**

An explosion and subsequent fire resulted in significant property damage at this 146,500 barrels-per-day refinery. The explosion occurred from a heat exchanger failure in the hydrode-sulfurization unit for light oil. The channel cover and lock ring of the 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 5 feet in diameter, and weighed 4,000 pounds and 2,000 pounds, respectively.

The hydrode-sulfurization 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 at approximately 3:55 p.m. The subsequent fire was brought under control in two hours and 45 minutes by firefighters using 15 fire trucks.

Explosion/Fire

October 8, 1992
Wilmington, California, United States
$73,300,000 **$96,000,000**

An explosion originating in the hydrogen processing unit occurred at 9:43 p.m. in this 75,000 barrels-per-day refinery. Extensive damage resulted to the hydrocracker, hydrode-sulfurization, and hydrogen processing units as a result of the explosion and subsequent fires, which were fueled by hydrocarbon released from the damaged process column and equipment. This 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 this 350-acre refinery.

The explosion resulted from the rupture of a six-inch carbon steel 90-degree elbow (outside radius) and release of a hydrocarbon/hydrogen mixture to the atmosphere. The vapor cloud ignited within seconds after the rupture at an undetermined point in the plant. A review of process data showed that there were no out-of-range or warning indications relevant to the incident until after the elbow had failed. The City of Los Angeles Department of Water and Power delivers electricity to the refinery and about 12 hours before the incident the city had a power outage. A review of the information showed that the power outage and restart were not a contributory cause of the incident. 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 Schedule 120 carbon steel elbow due to long-term erosion/corrosion.

The firefighting 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, under the observation of the Coast Guard, placed booms in the Dominguez Channel storm drain to stop oily water run-off generated by the firefighting effort from reaching the Los Angeles Harbor. The fire was finally extinguished at 2:00 a.m. on October 11.

Because of this incident, the refinery's gasoline production was reduced to 35,000 barrels-per-day, approximately 70 percent of rated capacity, until repairs to the damaged process units were complete. In early May 1993, the repairs to these damaged units were 95 percent complete.

Explosion/Fire

December 10, 1991
North Rhine, Westphalia, Germany
$50,500,000 **$62,000,000**

A pipe failure in the T-junctions area of a collector for an air cooler in the high pressure section of the hydrocracker unit resulted in a release of hydrocarbons and hydrogen, which subsequently ignited. A substantial part of this plant was destroyed by the explosion and subsequent fire. The cause of the pipe failure was attributed to an increase in erosion/corrosion behind the air cooler due to a plant process change.

Because of this incident, the hydrocracker unit was shut down for approximately seven months. A business interruption loss of nearly $90,000,000 was incurred at this plant.

Explosion

April 13, 1991
Sweeney, Texas, United States
$36,500,000 **$45,000,000**

A series of three explosions damaged the atmospheric residuum desulfurization (ARDS) unit and the adjacent hydro-treater at this 175,000 barrels-per-day refinery. The initial explosion occurred at approximately 2:25 p.m. and originated near the third reactor of the "B" train in the ARDS unit. This reactor, which was significantly damaged, had an 11-inch wall thickness and operated at approximately 2,000 psi of pressure. This 75,000 barrels-per-day ARDS unit was used to extract sulfur and heavy metals from crude oil in the refining process.

A downtime of approximately 17 months was required to replace the reactor and associated process equipment since there were relatively few suppliers capable of manufacturing or repairing this type of reactor. Additional factors in the length of downtime were the congestion of other process equipment near the damaged reactor and asbestos insulation in the ARDS unit. With respect to the restoration of the ARDS unit, approximately 36,000 barrels-per-day of throughput capacity was restored by December 1991 and 64,500 barrels-per-day by August 1992. The unit was back to full operating capacity by September 1992.

A business interruption loss of approximately $225,000,000 resulted from this incident.

Explosion/Fire

March 3, 1991
Lake Charles, Louisiana, United States
$23,000,000 **$28,000,000**

An explosion and fire occurred at approximately 11:00 p.m. in a 50,000 barrel-per-day FCC unit, which was being brought online after a seven-week shutdown for maintenance. During the startup, a drain valve at the bottom of a pressure vessel was improperly closed, letting water accumulate in the vessel. When superheated oil was allowed into the vessel and mixed with the water, a steam explosion resulted, rupturing the vessel. The oil released from this vessel ignited and fire engulfed the FCC unit.

After the explosion, plant operators isolated the involved FCC unit and two other FCC units at this refinery. The refinery fire brigade extinguished the fire at approximately 1:30 a.m. The two other FCC units were brought back on-line since they were not damaged by the explosion or subsequent fire.

The business interruption loss associated with this incident is estimated at $44,000,000.

Fire

November 3, 1991
Beaumont, Texas, United States
$15,000,000 **$18,000,000**

At approximately 2 a.m., a fire occurred in a crude unit of this 310,000 barrels-per-day refinery. This fire resulted from a seal failure on a process pump in this unit. Before the pump could be shut down and isolated, the fire spread, resulting in damage to the piping, pumps, instrumentation, and fin-fan coolers for this unit.

To control and extinguish the fire, a firefighting effort was required from the refinery fire brigade, municipal fire department, and fire brigades from nearby mutual aid companies. The firefighting effort brought the fire under control in three to four hours and achieved total extinguishment in approximately 10 hours. During the fire, water was drafted from the nearby Neches River and pumped into the refinery Inlet Canal to ensure an adequate water supply for the fire water pumps which take suction from this canal.

As a result of this incident, the crude unit was shut down for approximately 30 days for repairs.

Fire

January 12, 1991
Port Arthur, Texas, United States
$25,500,000 **$31,000,000**

A fire occurred as a result of a seal failure on a pump for the crude unit atmospheric tower. Before the pump could be shut down and isolated, a second product release occurred, spreading the fire. Subsequently, an elevated reflux drum and several process lines overheated and ruptured, increasing the damage to the unit.

As a result of this incident, the crude unit was shut down for six months, which resulted in a business interruption loss of approximately $76,000,000.

Fire

November 30, 1990
Ras Tanura, Saudi Arabia
$32.000.000 **$40,000,000**

A fire at this 530,000 barrels-per-day refinery completely damaged two fractionating columns, which were used in the production of kerosene and diesel fuel. As a result of this incident, the refinery was shut down for a two-week period to repair some of the damaged equipment. The refinery was then brought back online with a production capacity of 300,000 barrels-per-day.

The business interruption loss associated with this incident is estimated at $20,000,000.

Vapor Cloud Explosion

November 3, 1990
Chalmette, Louisiana, United States
$20,000,000 **$25,000,000**

At 11:21 p.m., a vapor cloud explosion occurred in the hydrocracker unit of this 160,000 barrels-per-day refinery. A mechanical failure involving the shell of a heat exchanger in this unit resulted in the formation of a vapor cloud, which was ignited by a heater. The subsequent fires in this unit burned for 10 to 12 hours before they were extinguished by the refinery fire brigade with mutual aid assistance.

As a result of this incident, the hydrocracker unit was shut down for approximately three months for repairs. However, the fire damage was limited to the hydrocracker unit and the refinery was brought back on-line within one week.

Explosion/Fire

April 1, 1990
Warren, Pennsylvania, United States
$25,000,000 **$29,580,000**

An operator was draining water from the debutanizer system of the (FCC) gas plant when liquified petroleum gas (LPG) was suddenly released. The LPG release continued at this 65,000 barrels-per-day refinery since the operator panicked and left the FCC gas plant. Subsequently, an ignition occurred resulting in an explosion and fire.

Vapor Cloud Explosion

December 24, 1989
Baton Rouge, Louisiana, United States
$68,900,000 **$89,000,000**

An eight-inch pipeline operating at approximately 700 psi 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 vapor cloud was ignited, causing an unconfined 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 3,600,000 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 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 firefighting had to be supplied with the remaining plant fire pumps and municipal fire trucks taking draft from alternate sources.

Approximately 48,000 gallons of AFFF foam concentrate, 200 fire brigade members, and 13 pumper units were used during the firefighting 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.

Hurricane

September 18, 1989
St Croix, Virgin Islands
$134,000,000 **$168,000,000**

Hurricane Hugo struck this refinery, causing extensive damage to 14 of the 500,000 to 600,000-barrel capacity storage tanks in the tank farm area, the administration building, and the company housing. The damage to process units, which were idled in preparation for the hurricane, was limited to the asbestos insulation on process columns and piping. A maximum wind speed of 192 mph was reported for 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-per-week for 15 weeks to remove the asbestos debris from the refinery at a substantial extra expense. Additionally, an outside 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.

Fire

September 5, 1989
Martinez, California, United States
$48,200,000 **$62,000,000**

A fire or explosion occurred in a hydro-treater unit which was processing feed stock from FCC unit at the time of the incident. A failure occurred in a line downstream from a separator, resulting in the release of hydrogen and hydrocarbons in the unit area. The cause of line failure, source of ignition, and process equipment involved is unknown at this time.

To control and extinguish the fire, a massive firefighting effort was required from the company fire brigade, fire brigades from the nearby refineries, and municipal fire department.

Fire

April 10, 1989
Richmond, California, United States
$87,170,000 **$112,000,000**

A 2-inch 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-foot high reactor in a hydrocracker unit. The steel skirt for this reactor, which was 10 to 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 loss, the hydrocracker unit was being shut down for maintenance and the reactor was in a hydrogen purge cycle. The initial hydrogen leak is believed to have resulted from the failure of an elbow to reducer weld in the 2-inch hydrogen preheat exchanger bypass line.

Because of this incident, approximately 25 percent of the refinery throughput capacity, including the complete hydrocracker unit production, was lost for a period of five months. Restoration of the hydrocracker itself required nearly two years.

Vapor Cloud Explosion

May 5, 1988
Norco, Louisiana, United States
$254,700,000 **$336,000,000**

Operations were normal in a 90,000 barrels-per-day FCC unit when internal corrosion caused the failure of the outside radius of an 8-inch 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 130°F) and the accumulator depressured 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-foot-diameter main fractionator from its 15-foot-high concrete pedestal. The column separated from its 10-foot-high skirt before falling. Analysis of bolt stretching of towers in the blast path indicated over-pressures as high as 10 psi.

The refinery immediately lost all utilities, including fire water and the four diesel fire pumps, greatly limiting the firefighting 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 barrels-per-day refinery. Blast damage throughout the plant was extensive, but was most severe in the 300-foot-by-600-foot FCC unit. About 5,200 property claims were received for off-site damage at distances up to six miles. The FCC unit eventually was demolished and a new unit was built.

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.

Explosion

March 22, 1987
Grangemouth, United Kingdom
$78,500,000 **$107,000,000**

A 29,000 barrels-per-day distillate hydrocracking unit was undergoing startup and was under hydrogen pressure and circulation with the hydrogen leak-off from the high pressure separator at 1,500 psi to the low pressure separator at 150 psi being regulated by two control valves in series. When the control valves were placed in manual mode, they opened fully and over-pressured the low pressure separator whose relief valves were not sized for such an occurrence. The 30-foot tall, 10-foot diameter separator exploded and disintegrated. One piece weighing three tons was thrown 3,300 feet.

Firefighting was conducted by the refinery fire brigade and 23 outside pumpers, foam trucks, and other equipment. Within one and one-half hours, 31 foam and water streams were discharging 12,000 U.S. gpm on the fire. Sewers were unable to cope with the flow and hydrocarbons began bubbling up from drains in other parts of the plant. The drainage system also became blocked by large quantities of a heavy waxy material. Eventually, water covered a 380,000-square-foot (8.7-acre) area. A total of 270,600 U.S. gallons of foam concentrate were used to blanket the hydrocarbon which was floating on the water. Final extinguishment was achieved approximately 19 hours after a nitrogen purge of the hydrocracking unit was initiated.

Fire

December 13, 1984
Las Piedras, Venezuela
$62,076,000 **$89,000,000**

A straight run of 8-inch line carrying hot oil from the high pressure separator to the low pressure stripper in a refinery hydrode sulfurizer fractured circumferentially in the parent metal in the heat zone about 1-1/2 inches from a weld. Hot oil at 700 psi and 650°F sprayed across the roadway into the hydrogen units where ignition occurred.

Intense fire around the pipeway in the hydrogen plant caused a 16-inch gas line to rupture, adding a second blow torch to the fire. In successive order, more pipes ruptured with explosive force in adjacent areas.

The fire caused a crash shutdown of the entire 600,000 barrel-per-day refinery. After six and one-half hours, the fire was extinguished. Damage was extensive. The three hydrogen plants and the four HDS units were heavily damaged or destroyed. Four years after the plant was built and nine years before the loss, the line which failed was judged as having excessive vibration. It is believed that the hot oil line failed in fatigue, largely due to hydrogen embrittlement.

Fire

August 15, 1984
Ft. McMurray, Alberta, Canada
$76,000,000 **$109,000,000**

Erosion failure in a 10-inch slurry recycle oil line in an 82,000 b/d fluid bed coking unit released liquids near their auto-ignition temperature. Vapors which covered a large area ignited almost immediately resulting in a large area ground fire which led to the failure of six or seven more lines. The fire eventually extended over a 150-foot area with damage up in the unit structure to over 100 feet.

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

The reactor fractionator, light gas-oil stripper, 15,000 horsepower air blower, pumps, pipe racks, etc., 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 firefighting efforts.

Explosion

July 23, 1984
Romeville, Illinois, United States
$191,000,000 **$275,000,000**

Just prior to the rupture of a 55 foot tall, 8-1/2 foot diameter monoethanolamine absorber column, a refinery operator noted a 6-inch 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 100°F propelled most of the 20-ton vessel 3,500 feet where it struck and toppled a 138,000 volt power transmission tower.

The weld separation occurred along a lower girth weld joint made during 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 alkylation units. After about one-half hour, a boiling liquid expanding vapor explosion (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 distant, causing a major fire there.

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 gpm electric fire pump inoperable. One explosion sheared off a hydrant barrel, resulting in a reduction of fire water pressure from the two 2,500 gpm 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 gpm fireboat eventually provided water at pressures sufficient for firefighting.

Fire

April 7, 1983
Avon, California, United States
$48,950,000 **$73,000,000**

Rupture of a 12-inch recycle slurry line in a 47,000 barrel-per-day FCC unit resulted in immediate ignition of the slurry. The failure occurred in a pipe rack 12 feet above grade. The slurry line pressure was estimated to be between 120 and 160 psi at a temperature of 600 to700 degrees. Shortly thereafter, a 600 psi steam line failed a few feet from the slurry line. It hampered firefighting efforts due to extreme noise levels and the vaporizing of liquid hydrocarbons. The water spray system for the pump row and the strong refinery water supplies allowed containment of the fire to a 70-foot by 140-foot area of the FCC unit. The FCC reactor, regenerator, fractionator, as well as related piping, instrumentation, and electrical equipment sustained severe damage.

Fire

August 20, 1981
Shuaiba, Kuwait
$42,000,000 **$73,000,000**

The cause of this refinery tank farm fire which destroyed eight tanks and damaged several others has not been disclosed. It appears to have originated at a pump manifold within the common dike serving six 160,000-barrel floating roof tanks containing petrochemical grade naphtha. Naphtha was being pumped into one of the tanks when the initial explosion and fire occurred.

About one-half hour into the fire, the seal of the first tank caught fire. This was followed rapidly by two others. These spread progressively, eventually involving five of the six tanks in the group. The sixth tank was empty and sustained severe damage.

A strong firefighting attack was initially made by the refinery fire brigade, later assisted by nearby industrial fire brigades, military and public fire departments. As many as 75 pieces of mobile firefighting equipment were used to supply up to 11,000 U.S. gpm of water and foam solution during the fire which lasted five days and 20 hours.

In spite of heavy protective water streams, a strong wind and radiated heat caused the fire to spread into an adjoining row of four 72,000-bbl floating roof tanks containing intermediate products and to a fixed roof 32,000-bbl slop tank. This took place 64 to 103 hours after the fire began.

Wind-driven flames caused the collapse of a heavily loaded unprotected steel pipe rack located between the two rows of three tanks. Water curtains set up between the tank groups and nearby process units at the 200,000 b/d refinery and petrochemical plant were effective. Damage was split fifty-fifty between liquid hydrocarbons and tanks and other equipment.

A piping or vessel failure in the 16,800 barrel-per-day HF alkylation unit was the cause of this incident. Reportedly, water accumulated in the flare system froze on contact with propane, forming an ice plug. Equipment in the alkylation unit over-pressured and subsequently failed. A large vapor cloud explosion and the ensuing fire destroyed the alkylation unit and boiler plant and resulted in varying degrees of damage to the crude, FCC, gas converter, reformer, and treating areas.

Because of this incident, the entire refinery was shut down for repairs.

Business interruption losses were minimized during the rebuilding of the HF alkylation unit by sending LPG feedstocks produced in the FCC to storage in nearby underground caverns.

Vapor Cloud Explosion

January 20, 1980
Borger, Texas, United States
$34,900,000 **$65,000,000**

Nearly simultaneous explosions aboard a 70,000 dwt tanker off-loading vacuum distillate and in an 80,000 barrel ethanol tank at a refinery occurred during a severe electrical storm. The ethanol tank was ignited when a plate section of the exploded tanker flew through the air and struck the tank, causing it to explode and burn.

The ship, tied up at the refinery dock, had discharged all but 50,000 barrels of its 128,000-barrel cargo when the explosion occurred. Unloading had been suspended minutes earlier because of a storm in the area. Explosions within the ship's holds spread 5,000 to 10,000 barrels of burning distillate on the water. This involved several nearby docks and four gasoline and crude oil barges.

The 120-foot diameter cone roof alcohol tank was about a third full. It burned itself out in about 14 minutes.

Explosion

September 1, 1979
Deer Park, Texas, United States
$68,000,000 **$138,000,000**

Liquid and gaseous hydrocarbons at 265 psi were released through failure of a 12-inch elbow in a line from a reflux accumulator serving the depropanizer overhead condensing system of a sulfuric-acid alkylation unit. An estimated 4,000 to 5,000 gallons of liquids were discharged, forming a large vapor cloud which traveled about 640 feet downwind to a FCC unit. Ignition occurred an estimated two minutes after the initial release. Both the alkylation and FCC unit, the CO boiler, and the control building sustained heavy structural damage. Four cooling towers and another control house were moderately damaged. Windows were broken 1-1/2 miles away.

Vapor Cloud Explosion

July 21, 1979
Texas City, Texas, United States
$23,000,000 **$47,000,000**

Vapor Cloud Explosion

October 3, 1978
Denver, Colorado, United States
$21,900,000 **$48,000,000**

Two weeks after the initial startup of a new catalytic polymerization unit, a pipe from the stabilizer reboiler failed and released propane gas. The resulting vapor cloud probably was ignited by a heater 300 feet from the point of release. The blast and ensuing fire destroyed the catalytic polymerization unit and heavily damaged other refining units.

Fire

May 30, 1978
Texas City, Texas, United States
$55,000,000 **$120,000,000**

The cause of this loss which started in the alkylation unit tank farm is unknown. An unidentified failure led to the release of light hydrocarbons which spread to an ignition source. A rather intense fire followed in the tank farm. In less than five minutes a 5,000-barrel sphere failed, causing a tremendous fireball and sending pieces of the sphere throughout the plant. Within the next 20 minutes, five 1,000-barrel horizontal vessels, four 1,000-barrels vertical vessels, and one additional 5,000-barrel sphere failed from either missile damage or BLEVEs. Pieces of the tanks traveled in all directions, falling into a number of operating units and tank farms, starting more fires. Fragments also hit the fire water storage tank and electric fire pumps, leaving only the two diesel fire pumps operational.

Explosion/Fire

August 17, 1975
Philadelphia, Pennsylvania,
United States
$13,000,000 **$34,000,000**

Crude oil was being off-loaded from a tanker at a refinery to a 60,000-barrel converted internal floating roof tank. Evidence indicates that while the tank had not actually overflowed at the time of the initial fire and explosion, it had been filled beyond the designed maximum fill height, and this caused rapid emission of volatile vapors from the tank vents. These traveled to a boiler house and its stack. The hot surface of an uninsulated high temperature and high pressure steampipe ignited the accumulated vapors. This caused a momentary overpressure of the stack that damaged it extensively. Flashback to the crude tank was immediate. Piping failures in the tank manifold released more crude oil outside of the tank dike.

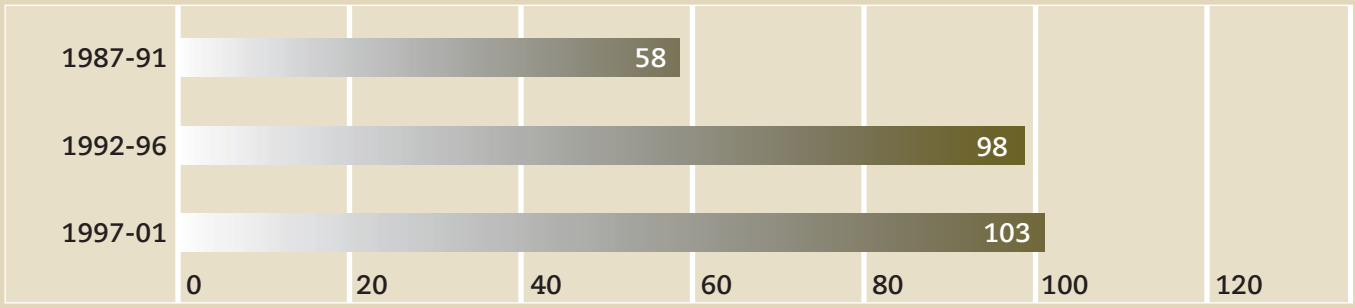
Within a brief time, an explosion occurred in the crude tank spilling additional oil into the dike. An adjoining tank containing No. 6 fuel oil became involved in fire and several pipelines in the dike failed. The fire burned for nine days before it was finally extinguished. During that time, it involved four tanks, the refinery administration building and other less important facilities.

Firefighting was by 200 municipal firefighters responding to 11 alarms and by several refinery fire departments. Three foam trucks and two pumpers were destroyed when fire flashed over oil-covered water. At times, as much as 13,000 gpm of fire water was pumped on the fire.

Petrochemical Plants

As with losses in the refinery category, the number of losses in the petrochemical industry have also continued to increase over the last few years, with the exception of facilities located outside the U.S. Outside the U.S., the number of losses in recent years has actually declined. Losses in recent years have been attributed to piping failures and management system failures. Total losses for the petrochemical incidents contained here, in January 2002 U.S. dollars, is approximately $4,000,000,000.

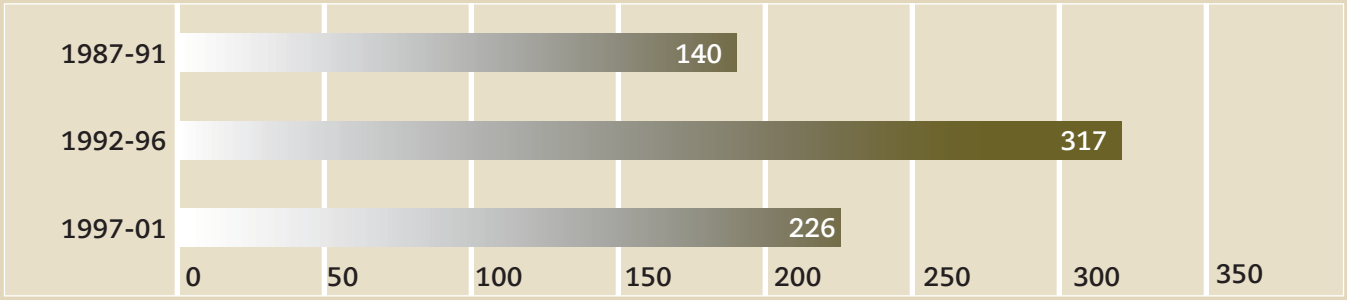
Petrochemical Losses in 5-Year Intervals **U.S.**



Although the number of losses in the petrochemical sector has increased in the U.S., the percentage increase over the last 5-year interval (1997-2001) is significantly less than the percentage increase over the previous intervals.

Petrochemical Plants

Petrochemical Losses in 5-Year Intervals **Outside U.S.**



After a significant rise in the number of losses outside the U.S. in the 1992 to 1996 period, the actual number of losses declined significantly in the 1997 to 2001 period. However, the severity of several losses (dollar-loss amount) heavily impacted the property insurance market.

A massive explosion occurred in an ammonium nitrate storage warehouse of a fertilizer plant just outside the southern French city of Toulouse. The warehouse contained approximately 300 tons of off-specification ammonium nitrate crystals. The explosion, with the strength of a 3.2 magnitude (Richter Scale) earthquake, left most of the plant in ruins and damaged surrounding areas. Thirty people were killed in the blast and approximately 3,000 were injured. The cause of the explosion is still in dispute and under investigation.

Explosion

September 21, 2001
Toulouse, France
$750,000,000

A release and ensuing fire in the polyacrylates plant destroyed the production plant and a warehouse. As a result of the fire, the plant will not be rebuilt. Two injuries resulted from this incident.

Fire

May 16, 2001
Birkenhead, United Kingdom
$109,000,000

Butadiene residue in an out-of-service storage tank caused a chemical reaction that initiated an explosion in a plastics resin unit of the facility. The tank was being cleaned at the time of the incident. The resulting fire took approximately three hours to extinguish. One person was killed and 69 people were injured, 32 of whom were contractors involved in cleaning the tank.

Fire/Explosion

March 27, 2000
Pasadena, Texas
$65,000,000 **$68,000,000**

The explosion occurred when potassium hydroxide was added to a vat instead of potassium carbonate at this insecticide production facility. The explosion injured 30 plant personnel as well as 20 neighboring residents. The facility was torn down and not rebuilt.

Explosion

June 8, 1999
Wuppertal, Germany
$75,000,000 **$79,000,000**

On June 22, 1997, an explosion and fire occurred in an olefins unit at this petrochemical plant. The incident originated at the cracked gas compressor in the olefins unit and was caused by a failed air assisted check valve on a 5-inch, 500 psi discharge line from the compressor. Upon closure of the check valve, one of the pins holding the two-piece check valve stem broke and allowed it to open in the opposite direction. This led to a gas leak, ignition, explosion, and ensuing fire at the partially enclosed compressor building. The explosion damaged a line to the quench tower, which fed the fire. The fire was allowed to burn itself out.

About 30 workers were treated for minor injuries. The olefins unit was down for approximately 10 months.

Explosion/Fire

June 22, 1997
Deer Park, Texas, United States
$100,000,000 **$108,000,000**

Petrochemical Plants

Explosion

December 13, 1994
Port Neal, Iowa, United States
$120,000,000 **$141,000,000**

Shortly after 6:00 a.m., 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 destroyed and a 30-foot wide crater was created. Additionally, metal fragments from the explosion punctured one of the plant's two 15,000-ton refrigerated storage tanks. The punctured tank released an estimated 5,700 tons of ammonia, causing the evacuation of approximately 2,500 people outside of the plant. Metal fragments also punctured a nitric acid tank, resulting in the release of approximately 100 tons of this acid. The explosion tore metal siding from adjacent buildings, damaged three third-party electric generating stations, broke windows of buildings 16 miles away in Sioux City, and was felt over 30 miles away.

As a result of this incident, a business interruption loss of $60,000,000 was estimated.

Flood

October 17, 1994
Baytown, Texas, United States
$25,000,000 **$29,000,000**

Heavy rains, amounting to approximately 25 inches throughout the greater Houston area, resulted in extensive flooding from surface water as well as overflowing streams. Most of the water that flooded this 90-acre plant, located approximately 30 miles east of Houston, came from the overflow of Cedar Bayou, which runs along the north site of this plant. Flood water covered this entire plant in depth ranging from two to five feet.

Plant management anticipated the flooding of the plant and was successful in shutting down all six process units in an orderly manner. Additionally, plant personnel were successful in relocating the smaller and lighter property items to higher ground. This effort notwithstanding, the flood waters caused extensive damage, mainly to computers, electrical substations, switchgear, pumps, motors, and buildings. At least 350 electric motors varying in size from 5 to 20 horsepower were completely submerged and required replacement while the larger electric motors with up to 1,500 horsepower were disassembled, baked out, and repaired.

The plant was shut down for approximately two months as a result of this flooding. During this period, the ethylene, polyethylene, olefins, and acetylene black production was shut down resulting in a business interruption loss estimated at $85,000,000.

Explosion

October 12, 1994
Pasadena, Texas, United States
$55,000,000 **$60,000,000**

On October 12, 1994, an explosion in a methanol unit at this facility caused extensive damage to process equipment and buildings. Shrapnel from the explosion also penetrated the outer shell of a large ammonia storage tank, which was nearby.

A mixture of combustible gases, which was left in the methanol plant piping and vessels during a shutdown due to incomplete purging, traveled to the flare stack where it was ignited. The burning gases flashed back through the flare drum and permitted the burning gases to reach the contact cooler where they exploded. Further damage was discovered to the refractory in the secondary reformer during startup after the explosion. The unit was down for six months.

Fire

August 8, 1994
Baton Rouge, Louisiana, United States
$25,000,000 **$29,000,000**

Operations at this 1.9 billion pounds-per-year ethylene plant were normal until a fire occurred at approximately 8:00 p.m. in one of the two ethylene trains at this plant. The fire, which was limited to the sponge fractionator column of the 1.5 billion pounds-per-year ethylene train, was brought under control early the next morning. Fire officials decided to allow the fire to continue to burn until it consumed the remaining hydrocarbon products in this train on August 11.

As a result of this incident, both of the ethylene trains at this plant were shut down. Plant personnel were successful in placing the 400 million pounds-per-year ethylene train back in service within two weeks. The ethylene production from this plant accounts for about four percent of the total U.S. ethylene production and 25 percent of this company's production.

As a result of this incident, the larger ethylene train was shut down for nine weeks to replace coke-plugged tubes in the furnaces caused by the emergency shutdown.

Petrochemical Plants

Explosion

May 27, 1994
Belpre, Ohio, United States
$100,000,000 **$118,000,000**

At approximately 6:30 a.m., an abnormal chemical reaction occurred during the batch production of a thermoplastic rubber product, resulting in an explosion at this plant. Because of the explosion, the reactor, process controls, appurtenances, control room, and building for this production were 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 p.m., the first of these four 1,000,000-gallon and one 500,000-gallon storage tanks containing styrene exploded. A firefighting attack utilizing cooling water and foam hose streams was used to prevent the fire from spreading to other nearby storage tanks, two of which contained butadiene. The fire was extinguished at approximately 3:30 p.m

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Explosion

July 28, 1992
Westlake, Louisiana, United States
$25,000,000 **$30,000,000**

At 7:10 p.m. a reactor in a urea manufacturing unit exploded, resulting in extensive damage at this chemical plant. The force of the explosion, which could be felt in areas up to 10 miles from the plant, drove 20 feet of the reactor support pedestal into the ground. The remaining 70 feet of the vessel failed catastrophically and fragments were propelled in all directions. Two pieces of the steel shell, each approximately 3 feet by 4 feet and weighing about 300 pounds, were found in the tank farm of a refinery located across an interstate highway and a railroad from the chemical plant. These two pieces traveled over 900 feet from their original site in the chemical plant.

The reactor, which was constructed in 1967, was 90 feet tall and 6 feet in diameter. This vessel was supported on a pedestal and had a 4-inch thick laminated shell. This shell consisted of 14 laminations, each approximately 3/8 inches thick, and a 1/2-inch thick stainless steel liner. The reactor was used in the conversion of carbon dioxide and ammonia and is believed to have been operating at design pressure and temperature (3,000 psi and 350°F) at the time of the explosion.

This incident resulted from an improper weld on a bracket supporting a tray inside the reactor. The bracket was welded to the stainless steel liner. The improper weld resulted in a carbamate leak and subsequent corrosion of the containment vessel. Reportedly, the leak went undetected for some time because weep holes in the vessel were not adequately checked to detect ammonia and carbon dioxide coming out ahead of the carbamate. As the carbamate progressed outward through the weep holes, it hardened and eventually clogged the holes.

Because of this incident, the urea production at this plant was shut down for more than 12 months. The business interruption loss for this incident is estimated at $20,000,000.

Vessel Rupture

January 13, 1992
Alvin, Texas, United States
$32,300,000 **$40,000,000**

A vessel in a raw-material process unit at this chemical plant ruptured during a cleaning operation at approximately 7:21 p.m. This vessel was a centrifugal feed tank with an 8,200 gallon capacity and maximum allowable working pressure of 15 psi.

The rupture and subsequent plant damage was caused by steam pressure that was generated by heat from a chemical reaction. A continuously increasing, highly exothermic reaction provided the heat source for the expanding supply of steam. The decomposition of this material resulted from overheating the vessel with steam to the coils during the cleaning operation.

The reconstruction of the new facility was completed one to two months ahead of schedule. Activities to mitigate the loss included the purchase of various raw materials from outside suppliers.

Explosion

June 20, 1991
Dhaka, Bangladesh
$71,000,000 **$88,000,000**

The failure of a welded joint between a carbon dioxide stripper and the main cylindrical body resulted in the release of high-pressure gas, which consisted of ammonia, carbon dioxide, and carbamate liquids. Subsequent to the release, an explosion resulted which caused significant damage to this fertilizer plant. The source of ignition for this explosion is unknown. This plant, which was constructed in 1970 and upgraded in 1988, has an annual production capacity of 340,000 tons.

Explosion/Fire

May 1, 1991
Sterlington, Louisiana, United States
$105,000,000 **$129,000,000**

Workers were preparing to check a compressor in the nitroparaffin unit when they noticed a small fire and sounded the plant fire alarm. Approximately 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 this 15-acre 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. The business interruption loss associated with this incident is estimated at $35,000,000.

Petrochemical Plants

Explosion

March 12, 1991
Seadrift, Texas, United States
$80,000,000 **$98,000,000**

At 1:18 a.m., an explosion occurred in the ethylene oxide process unit at this plant. As a result of the explosion, the ethylene oxide refining column was destroyed, the glycol ether unit was substantially damaged, and the co-generation unit was partially damaged. A pipe rack near the storage area for liquid ethylene oxide was damaged when a large piece of shrapnel from the explosion hit the rack, rupturing lines that contained methane and other hydrocarbon products. The subsequent fire that resulted from the release 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, a significant number of the water spray systems were damaged by the explosion or inadvertently actuated due to a loss of plant air. These systems were shut off and placed back in service as appropriate. A manual firefighting effort was used to extinguish the fire involving the pipe rack once the lines in the rack were isolated.

As a result of this incident, a business interruption loss of approximately $90,000,000 resulted mainly from the almost full-year reduction in ethylene oxide production. The polyethylene production was restarted in early April 1991, utilizing external source dethylene, while the olefins production was restarted in late April 1991.

Explosion/Fire

March 11, 1991
Coatzacoalcos, Mexico
$91,300,000 **$112,000,000**

At approximately 8:30 a.m., a gas leak involving the pipe rack that runs from Cangrejera to the terminal in this petrochemical complex lead to an explosion. This explosion, which occurred near the complex chemical plant, caused additional damage to the pipe rack resulting in a major gas leak. A powerful second explosion occurred that reportedly could be felt more than 15 miles from the complex. This explosion and the subsequent fire 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 in approximately three hours.

Because of this incident, the chemical plant at this complex was completely shut down for seven months, in which time the plant and the pipe rack were rebuilt. During this period, the vinyl chloride production at this complex was lost, disrupting most of Mexico's total annual output of 200,000 tons.

Explosion

November 6, 1990
Nagothane, India
$22,000,000 **$28,000,000**

A leak in a pipeline that transports ethane and propane to a gas cracker complex resulted in an explosion at an off-site gas-treatment and compression facility. Since the explosion took place outside the complex, the cracker and downstream units were not damaged, while the off-site facility experienced significant damage. The cracker was initially shut down due to feedstock supply problems but later was operating on a gas supply directly from the pipeline.

Prior to this incident, low density polyethylene (LDPE), linear low density polyethylene (LLDPE), high density polyethylene (HDPE), and polypropylene (PP) units were to be brought on-line within a few months. The commissioning of these units was expected to be delayed between four and 12 months due to this incident.

Vapor Cloud Explosion

October 23, 1989
Pasadena, Texas, United States
$675,000,000 **$869,000,000**

Shortly after 1:00 p.m., a large flow of ethylene, the reactant, and isobutane, a catalyst carrier, was released from one of the high-density polyethylene (HDPE) units at this chemical complex. The vapor cloud drifted northward toward the center of the HDPE process area before ignition, which is believed to have occurred approximately one minute after the release. Seismograph data from recording stations in the area suggested the blast was equivalent to the detonation of 10 tons of TNT.

The explosion destroyed two high-density polyethylene units, which included a total of eight particle-form, loop reactor trains. The heat from the explosion caused boiling liquid expanding vapor explosions of nearby pressure 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 8-inch ball valve on the No. 4 settling leg of a reactor in Plant V. The major function of this pneumatic valve 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 on Saturday, October 21. Due to changes in maintenance priorities, the work on settling leg No. 4 was not started until Monday, October 23.

After the explosion, investigations indicated that the lock-out device had been removed from the valve and the air hoses had been reconnected to the valve operator on settling leg No. 4. 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 spool leading to the product take-off valve should have been connected.

A business interruption loss in excess of $700,000,000 resulted from this incident since a period of approximately 24 months was required to restore the full HDPE production capacity at this chemical complex. This incident represents the largest single-owner property damage loss to occur in the petrochemical industry.

Vapor Cloud Explosion

June 7, 1989
Morris, Illinois, United States
$32,500,000 **$33,000,000**

After a power outage for the amine system and butane column, plant operators worked to restore normal operating conditions in the ethylene production area.

In the process of restoring operations, the vent valve for the depropanizer reflux drum was opened to reduce the pressure in this vessel. The vent line piping was arranged to route the excess product to the flare system or the gas compressor. Since the vent line to the compressor was out-of-service for maintenance, the excess propylene should have been routed to the flare system. However, the propylene was accidentally routed through the two-inch vent line to the compressor, forming a vapor cloud in the ethylene production area.

While plant personnel attempted to dissipate the vapor cloud with firewater monitors and hose streams, the vapor cloud was ignited. The source of ignition is believed to have been a spark from an incandescent light fixture. The bulb was apparently broken by the cold water of a hose stream or vibrated loose. The vapor cloud explosion damaged approximately 40 acres of this plant, including the ethylene production area.

As a result of this incident, the plant was shut down for approximately three months. During this period, only the polypropylene production was continued, resulting in a business interruption loss of approximately $55,000,000.

Explosion

March 7, 1989
Antwerp, Belgium
$77,000,000 **$99,000,000**

A hairline crack in a welded seam of piping to the level indicator system on the aldehyde column resulted in a minor ethylene oxide leak. 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 for the level indicator system was heated to such a degree that auto-decomposition of the ethylene oxide within the piping occurred. This auto-decomposition then propagated into the aldehyde column, which subsequently exploded.

The force of the explosion 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. Because of this incident, this plant was closed for at least 24 months and resulted in a business interruption loss of approximately $270,000,000.

Vapor Cloud Explosion

November 14, 1987
Pampa, Texas, United States
$215,300,000 **$288,000,000**

At 3:50 p.m. on Saturday afternoon, an explosion occurred in an air line in a reactor used for the liquid phase oxidation of butane. The explosion ruptured the external portion of the air line to the reactor. The reactor contents rapidly vaporized to the atmosphere and formed a vapor cloud. A vapor cloud explosion occurred about 25 to 30 seconds after the first explosion. The explosion occurred during startup. The explosion occurred because the reactor was not purged of air when it was shut down. There was extensive property damage in the immediate area and significant damage throughout the site. Windows were broken seven miles away.

A business interruption loss of approximately $140,000,000 resulted from this incident.

Petrochemical Plants

Fire

May 19, 1985
Priolo, Italy
$65,000,000 **$93,000,000**

Operations within this 600,000 metric ton-per-year ethylene plant were normal until a faulty temperature probe initiated an isolation of the hydrogenation equipment located within the cold section. While the operators were attempting to regain normal control, the pressure relief system came into operation. About the same time, fire was noted near grade level at the base of the de-ethanizer column. The source of fuel is believed to be 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 tall vertical propane tank exploded, its top section skyrocketing 1,500 feet and missing a gas holder by 30 feet. Two other propylene tanks toppled: one on a pipe rack and the other against an ethylene tank. All were protected by deluge waterspray systems that 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, pumps, etc., were severely damaged or destroyed.

Within a few minutes after the fire brigade responded, the ethylene column released its 9,300-gallon inventory, destroying one of the plant's two foam trucks. Assisted by outside firefighting agencies, the plant fire brigade brought the fire under control in 40 hours and finally extinguished it four days after ignition.

Explosion/Fire

May 6, 1982
Duluth, Minnesota, United States
$14,000,000 **$22,000,000**

An explosion occurred in the drying and grinding area of a chemical plant where fumaric acid was being processed. The ensuing fire spread rapidly through the area, into an adjoining process area and to the 60-foot by 120-foot warehouse, which was destroyed. Apparently, a static spark from an electric motor ignited dust from the powdered acid and caused the explosion. The fire was extinguished in approximately three hours.

Fire

April 18, 1982
Edmonton, Alberta, Canada
$21,000,000 **$33,000,000**

The release of high pressure ethylene from a 1/8-inch stainless steel instrument tubing leading to a gauge from a main line on the interstage piping system of a secondary compressor caused $20,000,000 damage to the low density polyethylene plant. An additional $1,000,000 damage was done to adjoining properties. The tubing failed as a result of transverse fatigue caused by vibrations from the reciprocating compressor. Ignition may have been by static electricity.

The unmanned compressor building was equipped with a combustible gas detection system; however, it failed to sound an alarm because of a faulty relay in the control room. Automatic fail-safe valves functioned properly, blocking the flow of ethylene but not before 450 pounds to 11,000 pounds of gas had escaped.

Explosion/Fire

March 9, 1982
Philadelphia, Pennsylvania, United States
$25,000,000 **$39,000,000**

One of three phenol units was destroyed and the other two damaged by an explosion and fire. The unit reportedly was shut down at the time 25,000 gallons of cumene hydroperoxide in an intermediate hold tank was being steam heated. Apparently, temperatures exceeded safe limits, leading to the venting of cumene from the system. This ignited explosively and caused the 25,000-gallon tank to rupture. Eventually two other process tanks and one containing fuel oil became involved.

The blast sheared off a 6-inch sprinkler riser; however, the plant's 1,500 gpm steam and electric fire pumps and two 2,500 gpm diesel fire pumps, augmented by 25 city fire department engine companies taking suction from city fire hydrants, were able to supply adequate water. The plant fire brigade, 160 city firefighters, and mutual aid workers from nearby chemical companies and refineries participated in controlling the fire.

Vapor Cloud Explosion

October 21, 1980
New Castle, Delaware, United States
$59,600,000 **$111,000,000**

Improper maintenance procedures during cleaning of a plugged recycle cooling line on a 10,000-gallon polypropylene reactor released hydrocarbons and polymer. Instead of removing only the motor operator of a 4-inch plug valve, the valve itself was accidentally removed. The release of 12,000 to 16,000 pounds of monomer at 150 psi produced a 250-foot by 450-foot vapor cloud that ignited after about two minutes.

The explosion broke flammable liquid lines throughout the three process trains and opened polymer lines in the finishing area. The blast also broke fire protection system risers, disrupting all firewater. Fires throughout the polymerization finishing and storage silo areas burned for over 10 hours. Two of the three process lines, the control building, and the finishing area were severely damaged. The compressor building, solvent recovery area, finished product warehouse, and cooling tower were moderately damaged.

The firefighting effort was accomplished with the use of 21 industrial fire brigades, and volunteer and paid fire departments.

Petrochemical Plants

Fire

May 17, 1980
Deer Park, Texas, United States
$18,745,000 **$35,000,000**

Vibration from a pump-bearing failure in the cumene section of a phenol acetone unit caused the pump seal to fail. The pump then released flammable liquid and vapor subsequently ignited. During the fire, several process pipes ruptured, adding fuel to the fire. Additionally, air coolers above the pipe rack collapsed, as did one process column.

Explosion/Fire

December 11, 1979
Ponce, Puerto Rico
$15,000,000 **$30,000,000**

This petrochemical complex, which produced dicyclopentadiene, isoprene, and paraxylene, had been shut down for 24 hours when a massive failure of a 13-foot diameter dimerizer vessel occurred. The 15 ton, 1-1/8 inch thick steel head traveled 1,900 feet to an adjoining paraxylene plant, landing on a propane refrigeration system and setting fire to one of its three units. The blast released 25,000 gallons of hydrocarbon liquids from the dimerizer as well as 80,000 gallons from a nearby solvent tank. Ignition was immediate, and fire damage extended over a 170 square feet, while the blast damage covered approximately 96,000 square feet.

As a result of this incident, approximately $5,000,000 of damage occurred in the isoprene plant and $10,000,000 of damage in the adjoining paraxylene plant.

Vapor Cloud Explosion

December 8, 1977
Brindisi, Italy
$28,280,000 **$66,000,000**

A major gas release in the cold section of a 230,000 metric ton-per-year ethylene unit ignited and caused severe blast and fire damage. Two nearby ethylene units were also damaged. The control building had brick panel walls within a reinforced concrete frame. Blast over-pressures blew out the wall panels and destroyed the controls. Water applied by 40 fire trucks could not be carried off by the sewers, resulting in an 18-inch backup of floating burning liquid and heavy hydrocarbons throughout the process area. The fires were controlled in eight hours and extinguished three days later.

Vapor Cloud Explosion

November 7, 1975
Beek, Netherlands
$22,892,000 **$61,000,000**

Cold brittle fracture of a 1.57-inch connection of a feed drum to its safety valve in an olefins unit naphtha cracker undergoing start-up caused the escape of an estimated three to five tons of hydrocarbons, mostly propylene. The subsequent explosion involved nearby storage tanks, buildings, and other parts of the plant as well as off-premises damage.

Vapor cloud explosion and ensuing fires resulted from a spill of 16,800 gallons of in-process hydrocarbon liquid and gases discharging through a broken expansion joint in the suction line of a pump. The explosion created blast waves that broke numerous process lines, resulting in multiple fires in the isoprene synthesis plant and adjoining tank farm. It also ruptured fire mains and disabled the fire pumps. A major explosion occurred when a 20,000 gallon isoprene storage tank ruptured approximately 15 minutes after the first explosion. About 90 minutes later, a 12 foot diameter by 200 foot high distillation column collapsed into the isoprene structure causing a flare-up and further involvement of thousands of gallons of hydrocarbons.

Vapor Cloud Explosion

November 29, 1974
Beaumont, Texas, United States
$16,000,000 **$47,000,000**

Massive failure of a 20-inch diameter bypass assembly around acyclohexane oxidation reactor caused the release of cyclohexane. The huge vapor cloud expanded into other areas of the plant that produced caprolactam and was ignited. The pressure waves from the explosion and the ensuing fire, involving an estimated 433,000 gallons of flammable liquids, destroyed much of the plant. Off premises damage extended eight miles and included 2,488 homes, shops, and factories.

Direct damage to the plant is estimated at $62,100,000 and damage to the surrounding community at $4,100,000.

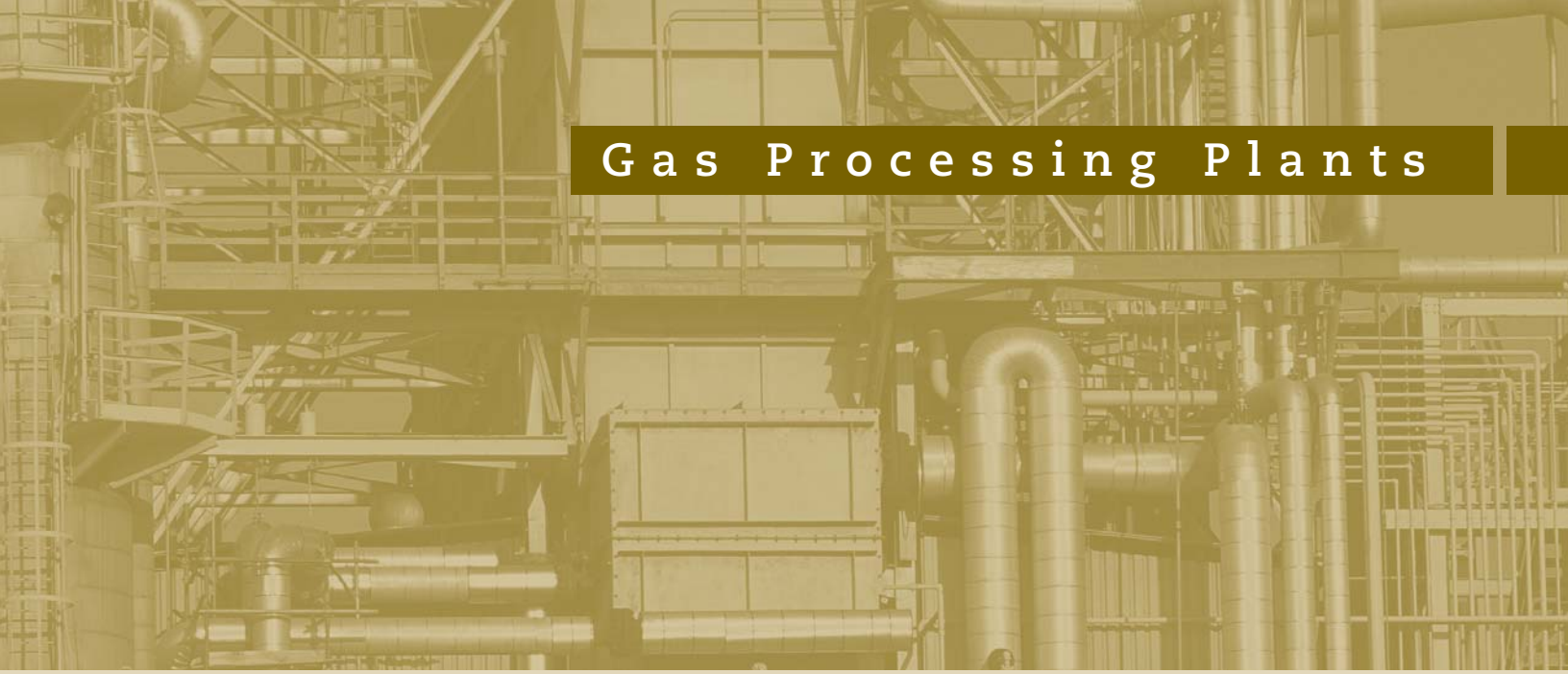
Vapor Cloud Explosion

June 1, 1974
Flixborough, United Kingdom
$62,100,000 **$182,000,000**

Inadvertent interruption of instrument air in an ethylene plant caused an accumulation of hydrogen in an acetylene hydrogenation column. An exothermic reaction occurred because ethylene hydrogenated to ethane, consequently decomposing ethane to methane, carbon, and hydrogen. Leakage resulted in fire and explosion.

Explosion/Fire

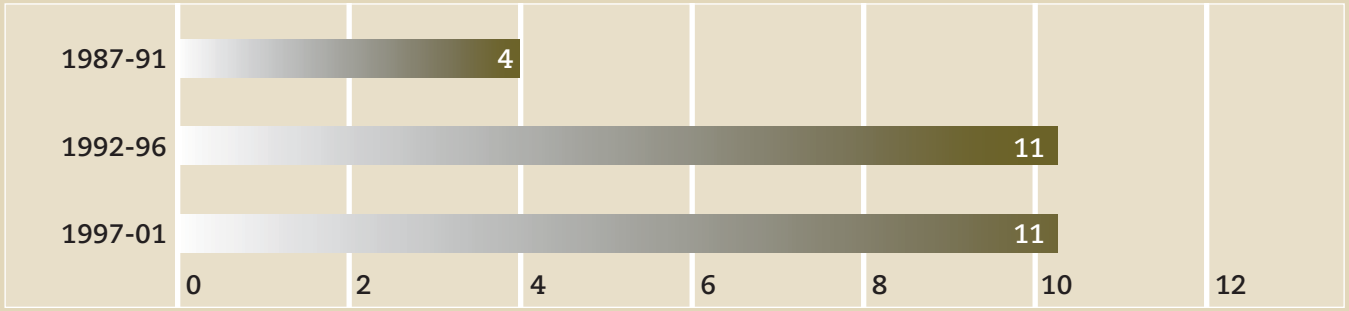
July 8, 1973
Tokuyama, Japan
$14,800,000 **$48,000,000**



Gas Processing Plants

Gas processing plants continue to be one of the safer types of plants in the hydrocarbon industry with regard to the number of property losses. Recent losses have been attributed to piping failures and cryogenic plant equipment failure and releases. Total losses for the gas processing plant incidents contained here, in January 2002 U.S. dollars, is approximately $1,000,000,000.

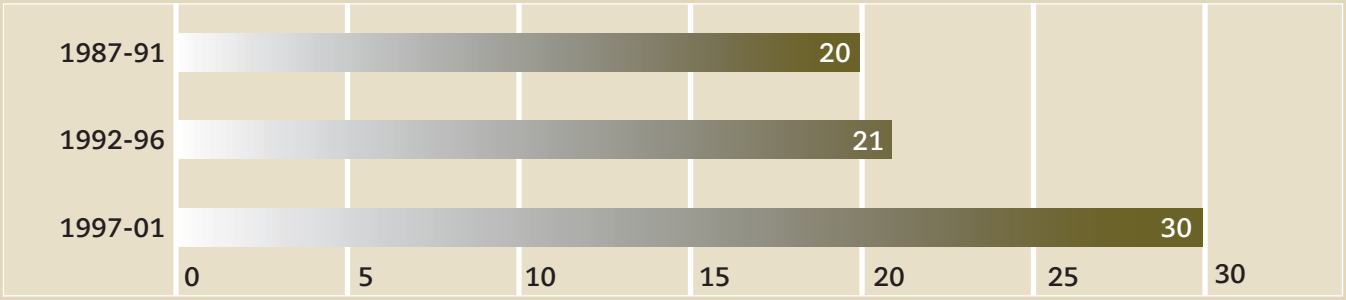
Gas Processing Plant Losses in 5-Year Intervals U.S.



The number of losses in gas processing plants in the U.S. has been very low over the last few years, even though there have been many new plants constructed to meet the need for natural gas. Due to the location of most of these types of facilities, plant layout, and separation between units is usually good, allowing for good ventilation and dispersion characteristics. This is particularly important at facilities that extract LPGs.

Gas Processing Plants

Gas Processing Plant Losses in 5-Year Intervals **Outside U.S.**



A number of gas processing plants outside the U.S. were severely impacted by natural hazard related events in the last few years. Also, the changing political landscape in many parts of the world has contributed to maintenance and operator training issues that have not been adequately addressed.

Two contractors were proving a liquid ethane meter when they noticed the hose unraveling. As they were closing valves to isolate the hose, the hose ruptured. The release of ethane ignited and caused a series of explosions and fires. The fire was allowed to burn itself out. Most of the damage was limited to the dehydration vessels, and downtime to rebuild was estimated at 6 to 9 months. Fifteen people were injured in the incident.

Explosion/Fire

January 27, 1999
Taylor, British Columbia
$23,000,000 **$24,000,000**

Gas supplies to Australia's Victoria State were virtually shut down following an explosion and fire at this 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 cited in the report issued by the Longford Royal Commission which was formed to study the incident.

Explosion

September 25, 1998
Victoria, Australia
$160,000,000 **$171,000,000**

At 10:30 p.m. on December 25, an explosion and fire occurred at a gas-to-liquids (GTL) plant in Bintulu, Sarawak. The fire was brought under control on December 26.

The plant is one of only two commercially successful GTL plants in the world with a capacity to produce 12,500 b/d of middle distillates and waxes from natural gas feedstocks. The explosion occurred in the air separation unit (ASU) that supplies oxygen for the production of synthesis gas feedstock. To date, the investigation into the incident points to an incipient 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. As of January 1998, the plant was estimated to be shut down for several months for repairs.

Explosion/Fire

December 25, 1997
Bintulu, Sarawak, Malaysia
$275,000,000 **$294,000,000**

Gas Processing Plants

Explosion

October, 1997
Mossel Bay, South Africa
$35,000,000 **$37,000,000**

During the startup of one of the three trains at this gas plant, light-off procedures for the gas reformer were not followed. This resulted in an accumulation of gas in the fire box and subsequent ignition and explosion. The reformer was significantly damaged, and estimated downtime for the unit is 10 to 11 months. The other two trains continued to operate.

Vapor Cloud Explosion

July 26, 1996
Cactus, Mexico
$136,000,000 **$148,000,000**

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 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.

On July 25, 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 on July 26. 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 in approximately three hours and protected the adjacent LPG spheres. If these spheres had failed due to BLEVE (boiling liquid expanding vapor explosion) 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. It is estimated that approximately 18 months will be required to repair or replace the damaged cryogenic units, including the associated control rooms.

Vapor Cloud Explosion

August 15, 1987
Ras Tanura, Saudi Arabia
$60,000,000 **$82,000,000**

A series of electric power interruptions caused several shutdowns of one or both of the identical 165,000 barrels-per-day gas fractionation process trains. The parallel trains were separated from one another by about 100 feet. At the time of the loss, propane feed to Plant I was about 100 percent of design capacity and about 25 percent of capacity of Plant II.

It is believed that there was a release of about 1,900 barrels of propane in Plant I over a half-hour period. Ignition of the large vapor cloud is believed to have been by a security vehicle that had stalled and was being restarted. The probable source of propane was a flange in a 4-inch relief valve line.

Vapor Cloud Explosion

September 30, 1984
Basile, Louisiana, United States
$30,000,000 **$43,000,000**

Failure of a threaded 1-1/2 inch drain connection on a rich oil line at the base of an absorber tower in a large (135 MMscfd) gas producing plant allowed the release of rich oil and gas at 850 psi at -40°F. The resulting vapor cloud probably ignited from the ignition system of engine driven recompressors. The 75 foot high by 10 foot diameter absorber tower eventually collapsed across the piperack and on two exchanger trains. Breaking pipelines added more fuel to the fire. Severe flame impingement on an 11,000-horsepower gas turbine driven compressor-waste heat recovery and super-heater train resulted in its near destruction.

Vessel Rupture

April 14, 1983
Bontang, Indonesia
$50,000,000 **$75,000,000**

The main cryogenic heat exchanger serving one of two identical 265 MMscfd processing trains of a liquefied natural gas plant ruptured violently. The investigation revealed that a valve on the 24-inch blowdown line that collected the discharge from various relief valves protecting both shell and internal coils of the main heat exchanger was closed. This effectively prevented the safety relief valves from performing their function. It also prevented a pressure controller at the top of the shell from operating, since it also discharged into the same header. It appears that this valve was omitted from the valve checklist for startup operations. Both trains were being started following a shut down to allow tie-ins from two additional newly constructed LNG trains.

The 141-foot by 14-foot diameter exchanger was designed for 60 psig and an operating pressure of 25.5 psig on the shell side. Gas from a source in excess of 500 psig caused massive failure of the exchanger. Fragments and coil sections of the all-aluminum 170-ton column were thrown as far as 160 feet. The ensuing fire was limited and extinguished in less than 30 minutes..

Gas Processing Plants

Vapor Cloud Explosion

April 15, 1978
Abqaiq, Saudi Arabia
$53,700,000 **$117,000,000**

A 22-inch gas transmission pipeline operating at 500 psig developed a leak due to corrosion. The leak expanded and the line parted, releasing a vapor cloud near a gas processing plant area that covered a 405-foot by 435-foot area. After about seven minutes, ignition occurred from a flare located 1,500 feet downwind. The jet/whipping action of escaping gas threw a 22-foot section of pipe 400 feet where it struck the vapor space of one of two 10,000-barrel spheroids. A second vapor cloud formed and was ignited, developing detonation over pressures of 7.8 psi.

Fire

April 3, 1977
Umm Said, Qatar
$76,350,000 **$179,000,000**

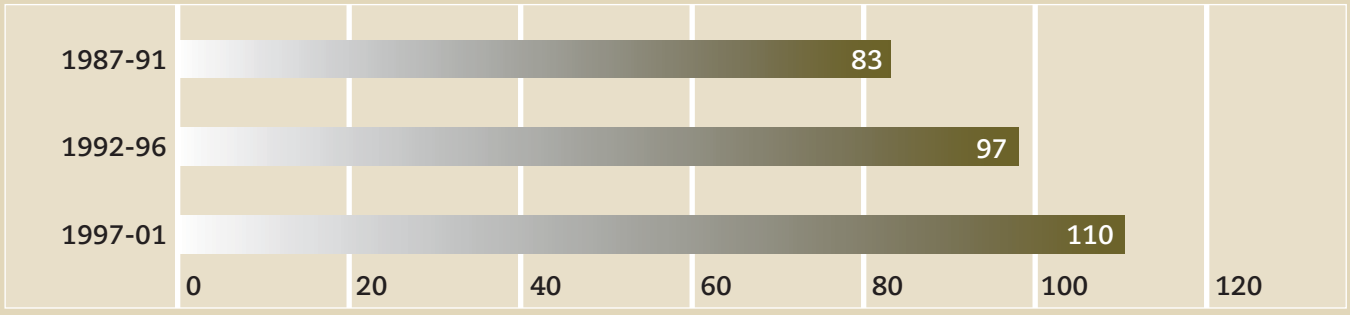
A 260,000-barrel tank containing about 236,000 barrels of refrigerated propane at 45°F failed massively. The wave of liquid propane swept over the dikes and inundated the 51,000-barrel-per-day process area before igniting. An adjoining tank containing 125,000 barrels of refrigerated butane also was destroyed as was most of the process area. The fire burned out of control for two days and was extinguished after eight days.

Reportedly, the tank weld that failed had been repaired following a weld failure incident a year earlier, when 14,000 barrels of propane were released. The April 3, 1977, weld failure was attributed to three possibilities including micro-biological sulfate reducing bacteria from hydrotesting the tank with sea water. In the first incident, a massive vapor cloud traveled 500 feet but did not ignite.

Terminals/Distribution

As with the other sectors of the hydrocarbon-petrochemical industry, the number of losses at terminals and other points of distribution have continued to increase. Recent large losses at terminals/distribution locations have been attributed to the overfilling of storage tanks and natural hazard related incidents. Total losses for the terminals/distribution facility incidents contained here, in January 2002 U.S. dollars, is approximately $363,000,000.

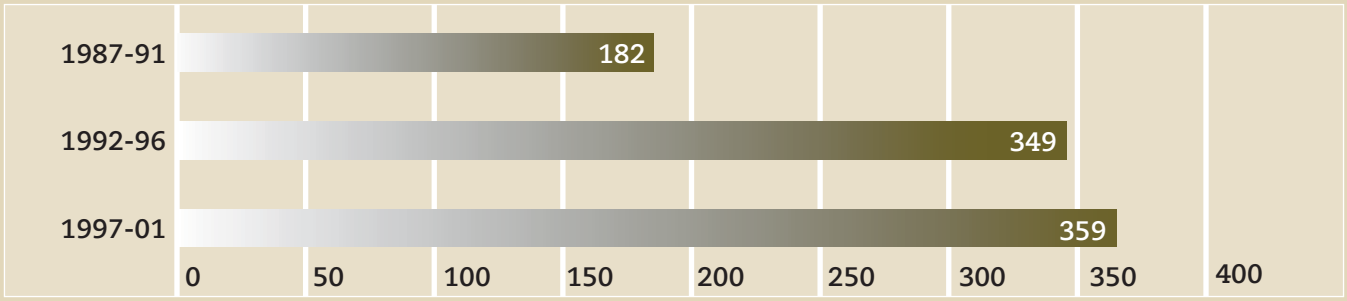
Terminals/Distribution Losses in 5-Year Intervals U.S.



As with the refinery sector of the industry in the U.S., the age of terminals/distribution facilities will become more of an issue in the next few years and require increased maintenance budgets to address tank inspections, pipeline inspections, and transportation infrastructure.

Terminals/Distribution

Terminals/Distribution Losses in 5-Year Intervals **Outside U.S.**



Although the number of losses in the terminals/distribution sector has increased outside the U.S., the percentage increase over the last 5-year interval (1997-2001) is significantly less than the percentage increase over the previous intervals.

All 16 tanks in this depot caught fire after one of them had been struck by lightning. Each of the tanks contained approximately 30,000 barrels of crude oil. The tanks were allowed to burn themselves out.

Fire

May 10, 1998
Ras Gharib, Egypt
$30,000,000 **$32,000,000**

A fire occurred at this 16-acre flammable liquids tank farm, which supplies jet fuel to an adjacent international airport. The fire burned for more than 55 hours, damaging seven storage tanks and consuming more than 1.6 million gallons of jet fuel. This tank farm contained a valve pit, south impounding area, north impounding area, and 12 storage tanks.

At approximately 9:20 a.m., the fuel supply company received a "no flow" indication in the pipeline to the tank farm. Shortly thereafter, the airport control tower noticed a column of black smoke from the tank farm. An initial fuel leak originating at an operating fuel pump in the valve pit was ignited by the electric motor for the pump, resulting in the fire. A cracked supply pipe in the valve pit formed two "V" shaped streams extending 25 to 30 feet into the air, providing additional fuel to the pool fire. As the fire continued, coupling gaskets in the piping deteriorated and more fuel flowed out of the storage tanks, substantially spreading the fire. Additionally, the valve controlling fuel flow in the supply line to the airport sporadically released fuel in the valve pit. Firefighters were unable to prevent the backflow of fuel from this line since the nearest manual shutoff valve was two miles from the tank farm.

At the initial fire alarm, the airport fire department dispatched four aircraft rescue and firefighting (ARFF) trucks and one rapid intervention vehicle. The second and third fire alarms provided an additional five pumpers, three trucks, and one rescue unit from the Denver Fire Department. In addition to the foam concentrate on hand, foam concentrate was received from fire departments in Seattle, Chicago, Houston, and other cities. After repeated unsuccessful attempts to extinguish the fire by the Denver Fire Department, a foam concentrate supply arrived from a foam manufacturer, and a private contracting company specializing in petroleum firefighting assisted the Denver Fire Department in extinguishing the fires throughout this tank farm.

Although the operations at the international airport were not affected by this incident, a significant property damage loss resulted at the tank farm.

Fire

November 25, 1990
Denver, Colorado, United States
$32,000,000 **$40,000,000**

Fire

December 21, 1985
Naples, Italy
$42,000,000 **$60,000,000**

Twenty-four of the 32 tanks at a large government owned marine petroleum products terminal were destroyed by a fire that began with a tank overfill. Twenty-seven thousand tons (715,000 barrels) of gasoline and fuel oil was being oil loaded into tanks, which reportedly were equipped with high-liquid-level gauges.

A large spill developed followed by a vapor cloud, which was ignited by an unknown source. Almost immediately 20 of the tanks were involved in a massive fire covering 3.7 acres. The devastating explosion destroyed the terminal buildings and extensively damaged nearby industrial and residential structures. Tank piping failed, contributing more fuel to the fire. The main firefighting control center as well as electric and engine-driven fire pumps and foam lines were disabled. Efforts to extinguish the fire were handicapped by intense heat radiation and by debris from the explosion.

About 800 firefighters with 166 pieces of mobile equipment responded from throughout south central Italy. This included airport crash trucks and even air tanker planes, which dropped foam on the fire. Four-hundred sixty tons (132,000 gallons) of foam were used. The fire was extinguished three and one-half days after it started.

Vapor Cloud Explosion

November 5, 1985
Mont Belvieu, Texas, United States
$42,970,000 **$61,000,000**

A contractor accidentally cut into a 10-inch propane line operating at 900 psi at a natural gas liquids terminal. The large vapor cloud, which covered an estimated 44 acres, was ignited about four to five minutes later by an unknown source. Liquid products from five of 26 salt-dome caverns fed the fire with an estimated 18,000 to 30,000 gallons of LPGs for almost six hours before they were blocked in and the fires extinguished. Both engine-driven fire pumps failed: one because intense radiated heat damaged its ignition wires and the other because the explosion broke a sight glass fuel gauge, which spilled diesel fuel that ignited and destroyed the fire pump engine.

Intense heat melted the large glass windows of the control center on the second floor of the office building, resulting in total loss of electronic equipment.

In addition to a large loss of NGL inventory and widespread structural damage throughout the terminal, radiated heat caused about $8,000,000 worth of damage to electronic and computer equipment.

Vapor Cloud Explosion

November 19, 1984
Mexico City, Mexico
$19,940,000 **$29,000,000**

This explosion and fire occurring at a government owned-and-operated LPG terminal is perhaps the most devastating such incident ever. Three refineries supplied the facility with up to 1,300,000 gallons of LPG daily. Tankage included six spheres and 48 bullets with a combined capacity of 4,242,000 gallons. Tanks were about 90 percent full at the time of the loss.

Product for storage was being received at 341 psig via a 12-inch pipeline from a refinery 250 miles away. The two largest spheres, each with a capacity of 630,000-gallons, and the 48 cylindrical tanks had been filled. The four remaining spheres, each with capacity for 420,000 gallons, were receiving product and were about one-half full when an 8-inch line to one of the spheres ruptured. The pressure drop was immediately sensed by the refinery operators.

Attempts to contact the terminal by telephone were unsuccessful and since the flow could only be stopped at the terminal it continued. About 10 minutes later the large vapor cloud that had formed was ignited by a grade level burn pit flare. Within five minutes of ignition, the first of a series of massive BLEVEs occurred producing a fire ball estimated to be 1,200 feet in diameter. The radiated heat from the rupturing tank and the missile damage allowed the release of more fuel from other tanks. Eventually, the four smaller spheres and 44 of the bullets' BLEVEs were ruptured by missiles. Some tanks weighing 20 tons skyrocketed, landing 3,900 feet away.

The terminal's firewater system was disabled in the initial blast. Water transported to the scene by 100 tank cars was used by firefighters to keep the two large spheres sufficiently cool to prevent their failure. These spheres developed leaks in their vapor spaces, allowing them to depressure and burn under controlled conditions.

Vapor Cloud Explosion

January 7, 1983
Newark, New Jersey, United States
$35,000,000 **$52,000,000**

Pipeline gasoline was being received into a 42,000-barrel internal floating roof tank at a products terminal when an overfill occurred, spilling about 1,300 barrels into the tank dike. A slight wind (1 to 5 mph) carried the developing vapor cloud about 1,000 feet to a drum reconditioning plant where an incinerator provided the ignition source.

The resulting explosion caused $10,000,000 damage to the terminal and up to $25,000,000 in over 2,000 claims to rail rolling stock and adjacent properties. Although dikes contained the burning spill to the tank that was overfilled, two adjoining internal floating roof tanks and a smaller transmix tank ignited and eventually were destroyed along with 120,000 barrels of product. Since the burning tanks presented little exposure to other facilities, the fire was allowed to burn itself out.

Explosion

January 8, 1979
Bantry Bay, Ireland
$20,566,000 **$42,000,000**

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

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

Vessel Rupture/Fire

May 26, 1983
Prudhoe Bay, Alaska, United States
$35,000,000 **$47,000,000**

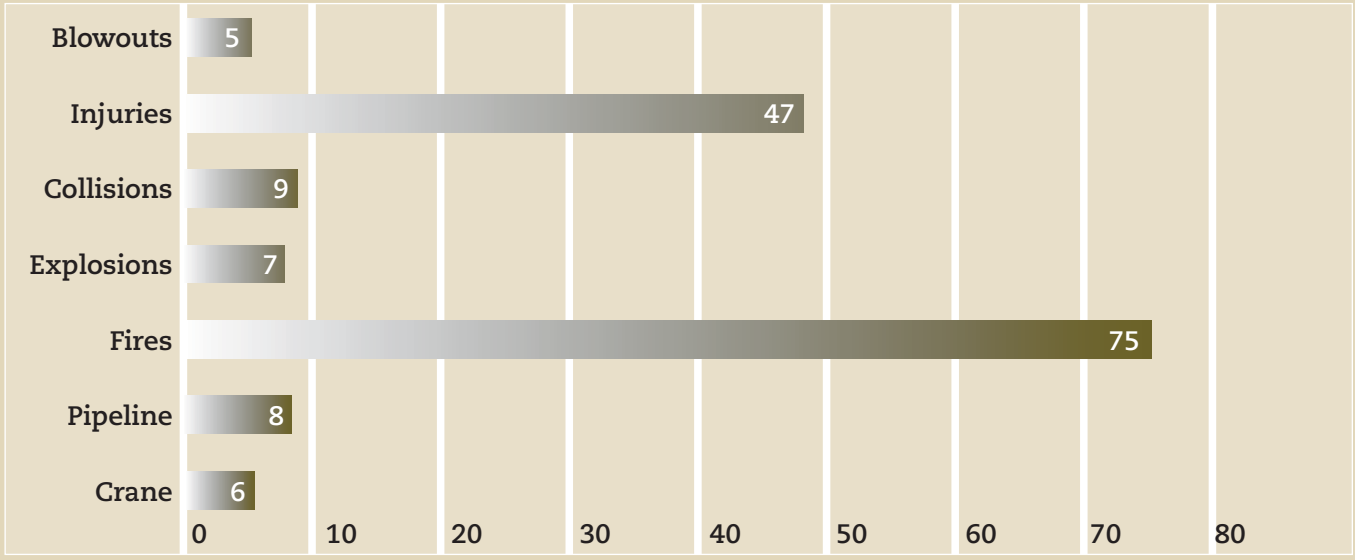
A low-pressure NGL feed surge drum in an NGL pilot plant ruptured violently at a crude oil flow station, resulting in direct damage and subsequent fire damage to one-third of the enclosing module as well as moderate fire exposure damage to the exterior of surrounding structures within 100 feet of the station. It is believed that high pressure from downstream vessels backed up past valves into the feed surge drum filling it with liquid product until it structurally failed. The equipment involved was not critical to oil production, so operations were suspended for only a short period of time.

Offshore

As with offshore experience in the Gulf of Mexico (GOM) in previous years, fires continue to be the most reported incident. Equipment failure and human error were the leading causes of the fires reported. Of the incidents reported in the last few years, well over half have occurred during production operations and less than 20% occurred during drilling operations. According to the Minerals Management Services (MMS) 1999 data, the rate of incidents per type of activity (production, drilling, workover, etc.) is the lowest it has been since 1995.

Total losses for the offshore incidents contained here, in January 2002 U.S. dollars, is approximately $3,800,000,000.

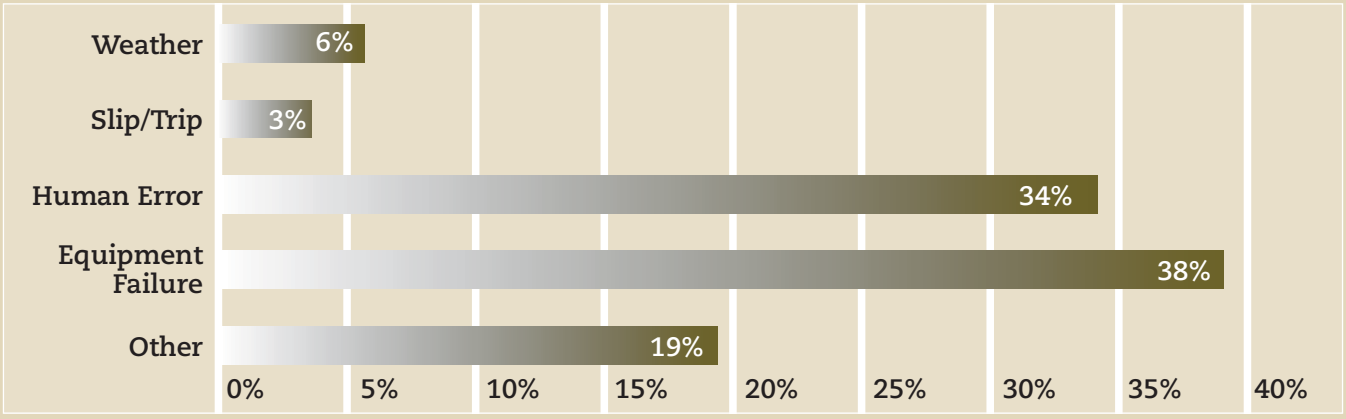
OCS Incidents* (GOM)-1999



*MMS Data

Offshore

Causes of OCS Incidents* (GOM)-1999



*MMS Data

On March 15, 2001, 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 semisubmersible, allowing seawater to enter the vessel. Workers pumped in nitrogen and compressed air and tried to pump out almost 3,000 tons of seawater to keep the rig afloat, but were unsuccessful. On March 20, the rig sank to the sea floor. The incident killed 10 workers. Lost production was estimated at $450,000,000.

Explosion/Fire/Sinking

March 15, 2001
Campos Basin, Brazil
$500,000,000 **$515,000,000**

A deck fabricated in Korea was in transit to Angola when it hit an underwater reef off the coast of Sumatra. The transport vessel capsized within four minutes in a water depth of 32 meters. Cause of the sinking has been attributed to the ship personnel's failure to follow the recommended route.

Mechanical Damage

November 2, 1999
Indonesia
$210,000,000 **$220,000,000**

A well began leaking as a repair crew was pumping water into an adjoining well. The subsequent gas leak ignited. The fire eventually spread to three wells. Two relief wells were drilled to kill the well.

Fire

March 11, 1999
Bombay High, India
$33,000,000 **$35,000,000**

One of two topside modules was dropped while being lifted for installation. The module struck a transport barge and the installation barge, causing an explosion. The module sank to the sea floor.

Explosion

December 3, 1998
Gulf of Mexico, United States
$110,000,000 **$116,000,000**

A pipe-laying barge was unable to maintain position due to a storm. During the incident, the hinged connections of the pipe-laying stringer fractured and fell to the sea bed, puncturing tanks in the barge's pontoons and damaging bottom plating.

Mechanical Damage

April 3, 1998
North Sea, Norway
$26,000,000 **$27,000,000**

During workover of a sub-sea completion by a jack-up rig, an engineer mistakenly opened a valve on the christmas tree. This released pressurized hydrocarbons that migrated to the surface, expelling sea water through the riser. The running tool fell 400 feet and onto the christmas tree below.

Mechanical Damage

March 2, 1998
North Sea, United Kingdom
$31,000,000 **$32,000,000**

Offshore

Explosion

March 25, 1993
Lake Maracaibo, Venezuela
$116,000,000 **$122,000,000**

An apparent failure of a propane intercooler liquid level control during unsupervised maintenance led to an explosion and fire. The control room on the main platform was destroyed and adjacent platforms were affected by the blast wave. Eleven fatalities resulted from the incident.

Hurricane

August 25, 1992
Gulf of Mexico, United States
$30,000,000 **$36,000,000**

On August 25, 1992, Hurricane Andrew entered the Gulf of Mexico after crossing the southern part of Florida. The storm was a Category Four hurricane with winds of up to 155 mph near the eye. Winds of 100 mph were recorded up to 25 miles from the eye. The areas hardest hit by the storm were the Ship Shoal and South Timbalier areas off the Louisiana coast.

Three platforms of one operator were toppled by the storm and a fourth was heavily damaged. Other major oil company facilities in the Gulf of Mexico also received varying degrees of damage, with the total damage from the hurricane estimated by the Minerals Management Service at $200,000,000.

Structural Failure

August 23, 1991
North Sea, Norway
$284,000,000 **$365,000,000**

A contractor was undertaking final submersion tests on a large gravity base structure that would support the main deck of the platform. The gravity base was approximately 110 meters tall, and approximately 600,000 tons of concrete were required to construct it. During the tests, contract personnel reported hearing a loud noise in one of the Willing shafts. The base began to take on water and in a matter of minutes had sunk in 200 meters of water. The cause of the cracking of the concrete was believed to be a design error. Other concrete base structures in the North Sea were surveyed for the same possible design problem as a result of this incident.

Explosion/Fire

March 19, 1989
Gulf of Mexico, United States
$40,000,000 **$67,000,000**

Contract personnel were installing a pig trap on an 18-inch sales 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 destruction of the platform and seven fatalities. Two years were required to replace the platform.

A semi-submersible drilling rig was in the process of drilling an exploratory well and had drilled to a depth of 16,000 feet. The well experienced a kick due to a high-pressure gas pocket. It is believed a malfunction occurred in sub-sea control equipment, allowing the gas to reach the surface and ignite. Gas also escaped from the sea bed and engulfed the rig in flames as it reached the surface. The rig was declared a total loss. The incident resulted in one fatality.

Blowout/Fire

September 22, 1988
North Sea, United Kingdom
$75,000,000 **$98,000,000**

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

In addition, the firewater pumps had been placed in the manual operation mode, because divers were 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 directly over the site of the initial release and resulting explosion and fire.

Fire/Explosion

July 6, 1988
North Sea, United Kingdom
$965,000,000 **$1,270,000,000**

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

Fire

April 24, 1988
Enchova Central Offshore, Brazil
$350,000,000 **$461,000,000**

Blowout/Fire

December 20, 1987
Cook Inlet, Alaska, United States
$125,000,000 **$171,000,000**

While cementing casing for a well, a shallow gas pocket was encountered. This caused a blowout and fire that significantly damaged the platform. The fire destroyed the helideck and damaged the accommodations module, drilling rig, and a crane boom. The incident delayed the start of production for several months. The platform damage was later repaired, and development drilling and enhanced oil recovery was resumed.

Blowout

November 4, 1987
Gulf of Mexico, United States
$200,000,000 **$274,000,000**

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.

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