

ONE HUNDRED LARGEST LOSSES - A THIRTY YEAR REVIEW OF PROPERTY DAMAGE
LOSSES IN THE HYDROCARBON-CHEMICAL INDUSTRIES*

Seventh Edition April, 1984

by
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This seventh edition covers the years 1954 through 1983. For 1983, seven fires and explosions are included among the 100 largest, trended property damage losses experienced by the hydrocarbon-chemical industries in the past 30 years. Also, included for the first time are three 1982 losses for which insufficient data was previously available. No losses qualifying for presentation in this study occurred in 1954.

The concentration of high property values and the inherent hazards of oil, gas, chemical and petrochemical operations combine to produce the very large losses evidenced by this review.

In the 30 year period covered, trended value of the average loss in each decade has increased from \$26,872,000 to \$36,797,000, or 37%.

	Number of Losses	Total of All Losses, Trended	Average Loss, Trended
1954-1963	13	\$ 349,340,000	\$26,872,000
1964-1973	32	884,454,000	27,639,000
1974-1983	55	2,023,841,000	36,797,000
TOTAL	100	\$3,257,635,000	\$32,576,000

Of the losses being reported for the first time in this edition, three involved petroleum tanks including a 600,000 barrel floater which was finally extinguished after a massive foam attack requiring the application of over 200,000 gallons of 6% foam. Two of the other new losses involved polymer extrusion facilities which in the past have had an enviable loss record. Three other losses involved pipe line or equipment failures, and another, a runaway reaction in a buried tank.

In the use of this data, it would be appropriate to recognise that:

- Loss history of the past 30 years is not absolutely an indicator of the type and magnitude of losses that may occur in the future.
- Historical factors do not reflect current concentration of values or the tendency to build single train units.
- Many large property damage losses have occurred during the course of construction prior to start up, however, these losses are not reflected in the study.
- This study relates to property damage only. If business interruption losses, third party liability claims and cost of workers' compensation were included, the number of incidents exceeding the \$10,000,000 criteria, used as a base for consideration, in this study, would increase greatly.
- While the study is most thorough, it may be that other losses could also have been included in the listing.

Many sources of information were used, and Marsh & McLennan are most grateful to the individuals who made contributions in preparing this study. They welcome any corrections or additional information on these 100 loss incidents.

*The IChemE would like to thank Marsh & McLennan Protection Consultants for permission to reprint this article.

**ONE HUNDRED LARGEST LOSSES
A THIRTY-YEAR REVIEW OF PROPERTY DAMAGE LOSSES
IN THE HYDROCARBON — CHEMICAL INDUSTRIES**

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Note: All losses are in U.S. dollars

<u>DATE</u>	<u>LOCATION</u>	<u>LOSS AT TIME OF OCCURRENCE</u>	<u>LOSS TRENDED TO 1/1/84</u>
1. 8/27/55	Whiting, IN	19,900,000	104,345,000

Detonation in a fluid hydroformer fragmented the process reactor, throwing missiles weighing up to 60 tons as far as 1,200 feet. The impact on tanks caused numerous fires which spread rapidly throughout the tank farm, ultimately bringing more than 40 acres within the fire area and eventually destroying 63 tanks and 1,270,000 barrels of crude oil and products.

Note: The trended loss estimated reflects oil price increases since August, 1955.

2. 1/17/56	Tanker, Lake Charles, LA	3,172,000	12,973,000
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An explosion occurred in the midsection of a 10,584 gross ton (130,000 barrel capacity) tanker which was loading a mixed cargo consisting of gasoline, No. 2 heating oil and kerosene at a refinery dock. The gasoline and heating oil loading had been completed, and the kerosene compartment being filled was about half full at the time of the explosion. The explosion blew a portion of the ship's side and deck on shore where they landed on the main cargo feeder lines to the docks. Three 10,000 barrel crude oil barges tied up at docks 100' and 600' distant burned, two sinking in the river.

The U.S. Coast Guard investigation concluded that the explosion occurred in a cargo tank into which kerosene was being introduced and that the discharge of static electricity generated by the splashing and turbulence ignited gasoline vapors in the tank. Adjoining cargo tanks had been filled with gasoline, and there is evidence that a leak had been discovered in the bulkhead between the gasoline and kerosene tanks just prior to loading of the kerosene.

3. 4/19/56	Marcus Hook, PA	3,000,000	12,270,000
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An explosion in a nitrogen oxide separation unit destroyed the unit and the adjoining hydrogen purification unit. The one-story masonry control building was also destroyed. The ensuing fire involved ethylene, the refrigerant for the separation unit. Deluge nozzles set up by the plant fire brigade kept equipment cool until all of the ethylene had been consumed. Cause of this loss has never been determined.

4. 1/8/57	Montreal East, Canada	3,164,000	11,960,000
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The gage failure on a 5,000 barrel sphere was discovered the day previous to the fire, and a series of errors in calculating liquid level in the tank over the next 24 hours resulted in overflowing through the vents of the sphere and into the diked area containing it and two larger butane spheres. Since outside temperature was 20°F and the boiling point of the butane was 30°F, a large quantity of liquid butane collected in the diked area. A large vapor cloud also developed and ignited, probably at a service station 600 feet away. The fire flashed back to the diked area.

About 30 minutes later, one sphere developed two small splits on top, and ½ hour after that the other two ruptured with great violence, throwing large missiles over a wide area. Flames from

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<u>DATE</u>	<u>LOCATION</u>	<u>LOSS AT TIME OF OCCURRENCE</u>	<u>LOSS TRENDED TO 1/1/84</u>
5. 1/29/57	Whiting, IN	4,900,000	18,522,000

the rapid burning of about 20,000 barrels of butane reached over a mile in height. Missiles struck many tanks, of which three ruptured and damaged pipe lines. A 30-ft long spherical-tank column support traveled 1,175 feet and struck a power substation, darkening most of the city of Montreal. Several buildings were set afire.

A 38,000-bbl tank containing 9,000 barrels of hot bunker fuel and a 30,000-bbl tank about half full of IP-4 fuel were pierced by missiles. Internal explosions blew the roofs off both tanks. An 80,000-bbl tank in a neighboring refinery containing 10,000 barrels of crude oil was also struck by a missile, which caused a violent explosion in the tank, blowing off the roof. The tanks were 600, 150, and 500 feet, respectively, from the butane spheres.

The refinery fire brigade with the help of public fire departments and private fire brigades brought the fire under control within 24 hours, but complete extinguishment took another 24 hours.

5. 1/29/57	Whiting, IN	4,900,000	18,522,000
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Three interconnected large pressure tanks in which propane from a sulfuric acid alkylation unit depropanizer was stored were destroyed by a violent explosion that occurred when a valve was opened to relieve pressure above the stored liquid propane. A high concentration of oxygen was probably an important factor responsible for the explosion.

6. 4/15/57	Nitro, WV	5,000,000	18,900,000
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During the batch chlorination step in the manufacture of methyl parathion, an explosion blew the cover of the glass-lined chlorinator through the roof of the three-story building, drove the vessel down into the floor and released flammable gases which ignited. Damage was extensive within a 1,000-foot radius.

7. 5/22/58	Signal Hill, CA	10,000,000	36,800,000
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A tank containing 50,000 barrels of hot oil feedstock frothed over, causing oil to flow over 27 of the 33 acres of a 20,000 barrel per day refinery. The burning wave of oil swept through approximately 70% of the process area and involved 73% of the refinery's tankage. Seventeen of 32 buildings were destroyed or damaged. Off-premises buildings and automobiles accounted for \$3,500,000 of the \$10,000,000 property damage.

8. 11/8/59	Tanker, Galena Park, TX	6,000,000	21,720,000
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Leaking gasoline from a cargo hose and from an adjoining barge which had previously been involved in a collision spilled on the water and was ignited down channel. The gasoline burned back to the tanker and barges.

9. 10/4/60	Kingsport, TN	9,500,000	34,010,000
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Nitrobenzene was being produced in a process using sulfuric acid as a scavenger for the water developed in the process. An upset in the remotely controlled process allowed a single phase

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DATE	LOCATION	LOSS AT TIME OF OCCURRENCE	LOSS TRENDED TO 1/1/84	DATE	LOCATION	LOSS AT TIME OF OCCURRENCE	LOSS TRENDED TO 1/1/84
	<p>mixture of benzene, mononitrobenzene, nitric acid and water to develop. The mixture, in the amount of 14,500 pounds equaled six tons of TNT. Detonation took place within the processing equipment.</p>						
10. 9/26/61	Tanker, Morehead City, NC	8,000,000	28,560,000				
	<p>Fuel spilled on the bay, became ignited and involved the 591 foot long tanker which then exploded. The fire burned itself out five days later.</p>						
11. 4/17/62	Brandenburg, KY	5,000,000	17,600,000				
	<p>Overpressure of a process reactor in an ethanalamine production unit forced a small amount of ammonia from the reactor through the ethylene oxide supply line to the ethylene oxide tank. The ammonia, acting as a catalyst, initiated an exothermic polymerization reaction in the 6,500 gallon tank. When the heat of reaction reached runaway proportions or reached the spontaneous decomposition temperature of ethylene oxide, the tank ruptured violently. Blast damage was severe.</p>						
12. 4/27/62	Marietta, OH	5,000,000	17,600,000				
	<p>A benzene recycle pump in a phenol production unit became plugged with residue. While employees were attempting to clear the plug with steam, pressure built up within a stripper column causing a 6-inch relief valve to operate, discharging benzene vapors which became ignited. Flying debris from the resultant explosion ruptured piping, releasing 40,000 gallons of various flammable liquids. These in turn were ignited.</p>						
13. 4/3/63	Plaquemine, LA	4,000,000	14,080,000				
	<p>The true cause of this ethylene plant explosion and fire is unknown. It is believed to have been the failure of a top sight glass on a separator on the feed to the dehydrators ahead of the methane distillation column. It operated at 500-600 psi and 60°F to 80°F. Thirty seconds after escaping gas was heard, there was a minor explosion which was followed in two or three minutes by a second explosion.</p>						
	<p>A severe fire ensued, which completely destroyed the production unit. An estimated 250,000 gallons of ethylene fed the fire.</p>						
14. 1/12/64	Attleboro, MA	5,000,000	17,350,000				
	<p>The illuminator port glass in a polyvinyl chloride reactor was replaced but was not pressure tested before the reactor was recharged. Upon recharging, operators observed a small leak. Upon tightening the clamp ring bolts, the leak intensified. About five to ten minutes later, a major explosion occurred causing extensive damage to the reactor building and adjoining buildings. Piping to all 20 reactors and other process equipment was broken, releasing 150,000 pounds of vinyl chloride which ignited immediately. Loss of boiler steam generation in sub-freezing weather resulted in extensive freeze-ups of other plant buildings.</p>						
15. 6/16/64	Niigata, Japan	22,000,000	76,380,000				
	<p>An earthquake of magnitude 7.7 resulted in two major fires in this 47,000 barrel per day refinery. The first fire, which started at the time of the quake, was the result of oil spillage over the sides of a floating roof tank. Friction sparks from the floating roof smashing against the sides of the tank caused ignition of the oil in the tank. Apparently the tank also developed leaks which allowed more oil to spill. Later, when the seismic wave engulfed the area, the oil was spread by floodwaters. However, the oil did not ignite for about four hours. Six hours after the initial quake,</p>						
	<p>an explosion occurred in another section of the refinery 1,200 feet from the original tank fire. This explosion also spread burning oil over the water. Although these two fires spread to within 350 feet of each other, they did not merge. Ninety-seven tanks containing 1,100,000 barrels of crude and product were destroyed. Damage to operating units was extensive.</p>						
16. 7/13/65	Lake Charles, LA	4,000,000	13,720,000				
	<p>Cryogenic liquids discharged from a relief valve in an ethylene plant to an 8" carbon steel flare header caused the header to fail. Ignition of the rapidly forming vapor cloud occurred almost immediately. Fire damage was extensive. Further details not available.</p>						
17. 8/25/65	Louisville, KY	10,000,000	34,300,000				
	<p>The manufacturing process involves the three-step conversion of acetylene gas to monovinylacetylene (MVA), then to chlorobutadiene (CD), and by polymerization, to neoprene. Mechanical failure in a compressor circulating gaseous MVA in the reactor system caused localized heating in metal moving parts to such an extent that the extremely high temperature initiated decomposition. A series of subsequent explosions was caused by fragments from the first explosion, flame impingement and transmission through pipelines.</p>						
18. 1/4/66	Feyzin (Lyons), France	18,100,000	60,092,000				
	<p>Improper sampling procedures on a 48 foot diameter 12,580 barrel butane sphere which was 3/4 full resulted in the uncontrolled release of liquid butane through a 2-inch connection. Ignition was believed to have been from a passing vehicle at a distance of 300 feet. Fire at the relief valves and at the base of the sphere burned about an hour before the tank failed massively. Pieces of steel up to 100 tons traveled about 1/4 mile. One fragment landed on a pipeway, cutting 40 lines. Another piece cut the legs out from under an adjoining sphere causing it to topple and break its 8-inch connecting line. Hot spots developed on 3 nearby butane tanks, and they ruptured.</p>						
19. 1/19/66	Raunheim, Germany	6,960,000	23,107,000				
	<p>Explosion in an ethylene plant is believed to have originated due to brittle fracture of a carbon steel compressor suction line. 600 pounds of methane were released. Buildings within 400 yards were damaged, and the ethylene unit was largely destroyed.</p>						
20. 10/13/66	LaSalle, Canada	3,500,000	11,620,000				
	<p>A runaway reaction in a polystyrene mass polymerization kettle necessitated manual dumping of the kettle contents. About the same time the rupture disc relieved to the roof of the three-story building. A large vapor cloud ignited destroying the polymerization building, the polystyrene warehouse and several other buildings. Fires were fed by both polymers and by about 60,000 to 80,000 pounds of monomer from a tank uphill from the building.</p>						
	<p>The blast disrupted power to the steam and electric fire pumps and broke sprinkler risers. Fire-fighting water was provided by a gasoline engine driven fire pump and by six fire department pumpers which drafted from a nearby canal.</p>						
21. 8-8-67	Lake Charles, LA	17,300,000	55,187,000				
	<p>An estimated 17,500 gallons of isobutane released by failure of a valve on an underground pipeline was dispersed over an area of 800 x 800 feet before igniting. The resulting explosion and fire</p>						

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			destroyed or heavily damaged two alkylation units, a delayed coking unit, a thermal cracker and a catalytic hydroforming unit. Two spherical tanks failed and numerous cone-roof tanks were involved.
22. 12/19/67	El Segundo, CA	3,700,000	31,630,000
			About 846,000 barrels of cracked bunker viscosity fuel oil were stored in a 780' x 460' oval-shaped reservoir 19 to 22 feet deep. A roof of built-up covering on wood planking covered the reservoir. Although protected by lightning rods, the 1MM barrel capacity basin was ignited by lightning. The roof was quickly consumed and the oil burned for 3 days before coking over with a porous crust. This was followed by 9 days of fire consisting of glowing coals. Several unsuccessful attempts were made to extinguish the 7 1/2-acre fire using 35 high and low expansion foam units assembled from industrial and governmental agencies. Finally, 30,000 cubic yards of sand were spread over the crusted oil which eventually thickened to depths of about 6 feet. The trended loss estimate reflects oil price increases since December, 1967.
23. 1/20/68	Pernis, The Netherlands	28,000,000	85,400,000
			Frothing occurred when hot oil and water emulsion in a tank reacted with volatile portions of hydrocarbonic slop, causing a violent vapor release and boil-over. The ensuing fire involved 30 acres of the approximately 200-acre refinery, the second largest in the world. Two wax crackers, a naphtha cracker, a sulfur plant and 80 tanks were destroyed or damaged. Much of the property involved in this loss was idle or obsolete. Off-premises damage was reported as far as 9 1/2 miles.
24. 7/10/68	Roswell, NM	4,000,000	12,200,000
			Rupture of a gasket in a 16" discharge line from one of three 3100 horsepower reciprocating compressors at a new natural gas transmission station was the cause of this loss. The station was operated by remote control, but two employees were on the premises doing maintenance work. Upon hearing gas escape at 700 psi, one worker went to the control board to shut all engines down. Before this could be accomplished, the fire started. Ignition may have been from several sources including friction between metal parts, static electricity, or rupture of the sheathed cables of the ignition circuits. The compressors were destroyed and the engines heavily damaged.
25. 1/14/69	Lake Charles, LA	4,510,000	13,124,000
			Mechanical failure of a batch alcohol reactor containing about 2,000 gallons of kerosene and aluminum triethyl under high pressure caused a flash fire and localized blast damage including destruction of the process control room. The reactor head landed in a pipe rack 80' distant but did not rupture the lines.
26. 3/6/69	Puerto La Cruz, VZ	4,652,000	13,537,000
			A leaking valve or piping in a refinery crude unit allowed hydrocarbon vapors to drift to a heater where they were ignited. The ensuing fire involved a heater-treater vessel which ultimately ruptured. A number of explosions caused minor damage at distances up to 6 miles. Twenty-four tanks, eight buildings, a visbreaker and the crude-vacuum units were destroyed.
27. 8/12/69	Flemington, NJ	4,161,000	12,109,000
			An employee working in a PVC Reactor building slipped and inadvertently grabbed the handle on a quarter-turn dump valve for one of the 15 reactors, shearing off the stem. Attempts to

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			stop the flow of vinyl chloride monomer from the 3" pipe were unsuccessful. The building was evacuated as gas flowed along the ground to a bulk storage tank area where a tank truck was being loaded with powdered PVC resin through a 10" plastic feed line. Ignition of the gas probably was by static electricity from the plastic line. The explosion caused heavy structural damage to the two-story steel-framed reactor building which had concrete floors and roof and masonry block and asbestos-cement walls. Because of VCM piping damage and lack of accessible shut-off valves, the ensuing fire burned for six days until the VCM system depressured.
28. 10/1/69	Escombreras, Spain	12,378,000	36,020,000
			Propane vapors released from bullets drifted 600 feet and were ignited by cooling tower motors. Further details not available.
29. 10/23/69	Texas City, TX	8,000,000	23,280,000
			The 100 foot high refining column in the butadiene unit of the billion pound per year olefins complex disintegrated with explosive ignition of 540 gallons of liquid hold-up. Sections of metal plate were spread uniformly over a radius of 1,500 feet. One section weighing about 800 pounds traveled 3,000 feet. All five towers in the butadiene section were either felled or heavily damaged.
30. 2/5/70	Hammond, IN	5,500,000	14,960,000
			Three separate fires in a fully sprinklered 300' x 420' fire resistive TBA Warehouse were attributed to arsonists apparently to conceal inventory shortages. There was an 18-minute delay in notifying the fire department. When fire fighters arrived, flames were coming through the precast concrete roof and had involved all areas of the structure, which contained petroleum products and tires.
31. 8/3/70	Corpus Christi, TX	7,400,000	20,128,000
			Hurricane "Celia" with winds of 140 to 160 MPH and 6 to 8 inches of rain struck this 85,000 BPCD refinery. The main structure of a 19-year old Thermoform Catalytic cracking unit was toppled. About 30 tanks were damaged to varying degrees. Off-premises power was disrupted for several weeks, as was city water which provides makeup to the service and fire water pumps.
32. 9/17/70	Beaumont, TX	6,500,000	17,680,000
			Lightning struck a 15,000 barrel slop oil tank with resulting failure of the floor-shell seam. 11,000 barrels of oil were released, spreading to involve 16 nearby undiked tanks, pipe right-of-ways and a cooling tower. The fire burned for 12 hours before extinguishment.
33. 12/5/70	Linden, NJ	27,173,000	73,916,000
			A 7" thick reactor of a wide-range hydrocracking unit being operated by computer at 2500 psi failed explosively due to localized overheating. The blast caused widespread damage over a 300-yard radius including an adjoining cat cracker and crude pipe still where the roof of the control building collapsed. Other units were safely shut down from a blast-resistant control building which sustained minor damage. There were over 7,000 claims of property damage from outside of the refinery.
34. 2/26/71	Longview, TX	5,670,000	14,402,000
			A drain fitting on piping between the booster and 40,000 psi high pressure compressors broke allowing ethylene to accumulate. Automatic equipment promptly detected the hazardous

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DATE	LOCATION	LOSS AT TIME OF OCCURRENCE	LOSS TRENDED TO 1/1/84
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vapor and operated the automatic high-density water-spray system designed to wash ethylene from the atmosphere. Apparently the leak was too large for the spray system to handle. Ethylene entered the exhaust system of an engine which was driving one of the compressors causing the muffler to detonate, thus igniting the rest of the vapors.

The explosions, which were felt six miles away, destroyed 12 buildings and caused lesser damage throughout the polyethylene plant and to the surrounding properties.

35.	4/21/71	Covington, GA	5,000,000	12,700,000
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Sparks from a short circuit in the extruder/roll storage room were the cause of this fire which destroyed most of this polystyrene foaming and forming plant. Initial attempts to extinguish the fire with extinguishers and 1 1/2-inch log lines were unsuccessful. Fire detectors actuated a high expansion foam unit, but it was unable to keep up with the rapid spread of fire. Open fire doors, which were arranged to close automatically, failed to do so, and the fire spread to the thermoforming room which had no fixed protection. Two other fire walls failed and fire communicated to the reclaim room and the finished product rack storage warehouse. A high-ex unit in the warehouse also was ineffective due to the extremely rapid spread of fire.

Public fire departments responded but were able to save only 20% of the 150,000 sq ft plant, a warehouse cutoff from the main complex by a masonry fire wall having no openings. The presence of residual isopentane vapors escaping from the foamed styrene caused the rapid development and spread of this fire.

36.	8/19/71	Bound Brook, NY	10,000,000	25,400,000
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Flood waters from eleven inches of rain and a burst dam damaged chemical plant.

37.	2/29/72	Delaware City, DE	6,002,000	14,705,000
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A transfer line failure 250 ft. above grade in a fluid coking unit dumped hot oil. Difficulty in blocking in the line and stopping the flow resulted in damage to the coking drum structure.

38.	3/30/72	Rio de Janeiro, Brazil	4,800,000	11,760,000
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The LPG storage area of this 256,000 barrel per day refinery included five 10,000 barrel spheres and sixteen bullets. Protection consisted of fixed cooling water systems on the spheres and monitor nozzles and hydrants for the horizontal tanks.

Water was being drained from one of the spheres through a 2-inch pipe with a 2-inch gate valve pointing down at a height of 6 feet from ground level. The operator left with the drain valve fully open. When he returned, liquid LPG was pouring from the drain at 156 psi, and he was unable to reach the valve because of the cold zone and because the jet had dug a large hole in the crushed stone bed covering the ground. A very large vapor cloud developed spreading beyond the refinery boundary. It ignited and flashed back to the sphere. Flaming LPG from the drain hitting the ground was deflected back against the lower part of the tank. Cooling water was applied to all tanks. After 15 to 20 minutes, the relief valve opened at 239 psi discharging gas to atmosphere. It promptly ignited.

Despite the cooling water and open safety valve, the sphere exploded, causing a tremendous blast wave and leaving only a crater where the sphere had been. Nearby spheres and some of the bullets were thrown from their supports. Lines were broken, so that the fire spread throughout the storage area. Following the explosion, the fire developed beyond any possible control, causing the explosion of three more horizontal tanks and finally burning itself out.

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*Indicates New Loss Incidents Reported as of the 1984 Seventh Edition.

DATE	LOCATION	LOSS AT TIME OF OCCURRENCE	LOSS TRENDED TO 1/1/84
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All 21 tanks were destroyed. Many refinery buildings and facilities sustained blast damage. Two fire trucks were destroyed and another four were damaged.

39.	8/4/72	Trieste, Italy	10,620,000	26,019,000
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Terrorists placed dynamite charges at the 40-inch discharge lines of four 250-ft. diameter 500,000 barrel floating roof crude storage tanks. Two tanks were totally destroyed, three were badly damaged and three others received less severe damage. When the bombs exploded, two tanks became involved in severe pit fires which spread to the roof seals. Once the roof sank, boil-overs occurred spreading oil over the 9-foot high individual dikes. Burning oil flowed to the terminal control house 1600-2000 feet away. All tanks were protected by rim-foam systems.

Note: The trended loss estimate reflects crude price increases since August, 1972.

* 40.	8/14/72	Billings, MT	5,000,000	12,250,000
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An alkylation unit was being started up after shutdown because of an electrical outage. When adequate circulation could not be maintained in a deisobutanizer heater circuit, it was decided to clean the strainer. Workmen had depressurized the pipe and removed all but three of the flange bolts when a pressure release blew a black material from the flange, followed by butane vapors. These vapors were carried to a furnace 100 feet away, where they ignited, flashing back to the flange.

The ensuing fire exposed a fractionation tower and horizontal receiver drums. These drums exploded, rupturing pipelines, which added more fuel. The explosions and heat caused loss of insulation from the 8-foot-by-122-foot fractionator tower, causing it to weaken and fall across two major pipe lanes, breaking piping — which added more fuel to the fire. Extinguishment, achieved basically by isolating the fuel sources, took 2 1/2 hours.

The fault was traced to a 10-inch valve that had been prevented from closing the last 3/4-inch by a fine powder of carbon and iron oxide. When the flange was opened this powder blew out, allowing liquid butane to be released.

41.	10/25/72	Carteret, NJ	5,000,000	12,250,000
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A series of three explosions occurred on an oil barge that was being loaded at a terminal pier, partly with No. 2 fuel oil and partly with gasoline. Flaming liquids on the water spread to dockside facilities, a bulk storage plant and another oil docking facility. Burning oil entered the intake of a large public utility generating station. Extinguishment came 48 hours later through the combined efforts of 5 municipal fire departments and 4 plant fire brigades.

42.	2/10/73	Staten Island, NY	14,000,000	33,040,000
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A 600,000 barrel reinforced and prestressed concrete LNG tank had been out of service for a year after instrument readings indicated a leak in the liner. The inside of the tank was insulated with polyurethane and had a liquid and vapor tight laminated liner consisting of Mylar, aluminum and Dacron. The 61' x 268' tank had been purged with nitrogen and air before repairs commenced and was regularly tested as work progressed on repairs. Eleven months after the initial purge, fire broke out in the tank from an unknown ignition source. The first material ignited was either the liner or a small quantity of natural gas that escaped into the tank from the insulation or the berm around the tank. The polyurethane foam ignited and generated sufficient heated gases and pressure to lift the concrete dome which then fell back into the tank.

<u>DATE</u>	<u>LOCATION</u>	<u>LOSS AT TIME OF OCCURRENCE</u>	<u>LOSS TRENDED TO 1/1/84</u>
66. 10/3/78	Denver, CO	21,927,000	32,452,000
<p>Two weeks after the initial start-up of a new cat poly 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 cat poly unit and heavily damaged other refining units.</p>			
67. 10/30/78	Pitesti, Rumania	13,000,000	19,240,000
<p>An overhead line from a tower to cooler fractured in the propylene fractionation section of a 40,000 b/d refinery. The mix of propane-propylene formed a massive vapor cloud which ignited, causing heavy blast and fire damage. Windows were broken 6 miles away.</p>			
68. 1/8/79	Bantry Bay, Ireland	20,566,000	27,764,000
<p>An eleven-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 ten minutes later fire spread aft along the length of the ship and was observed on the sea at both sides of the ship. After a half 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 an excessive stress due to incorrect ballasting at the time of the disaster.</p> <p>A fragment of the ship weighing 1,000 pounds was found in the terminal at the base of a "Jumbo" crude oil tank, a distance of 1,800 feet from the ship. In addition to total loss of the ship, 1,130 feet of the concrete and steel jetty were damaged or destroyed.</p>			
69. 3/20/79	Linden, NJ	17,500,000	23,625,000
<p>Failure of a dead-ended section of piping in a fluid catalytic cracking unit allowed the release of propane and butane. The developing vapor cloud had covered an area of approximately 1½ acres to a depth of 5-6 feet when ignited. Water sprays were ineffective in dispersing the vapors. An unused control room filled with vapors exploded. Flying bricks and debris severed small lines in the area releasing hydrocarbons.</p>			
70. 4/19/79	Port Neches, TX	32,000,000	43,200,000
<p>An 854'-long 123,692 DWT tanker had off-loaded its cargo of crude oil and was taking on ballast water when struck by lightning. Two explosions followed, and the forward four crude tanks caught fire. High winds hampered fire-fighting efforts. Most of the damage was to the ship, but the refinery dock was extensively damaged. Further details not available.</p>			
71. 7/21/79	Texas City, TX	24,000,000	32,400,000
<p>Liquid and gaseous hydrocarbons at 265 psi were released through failure of a 12" 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 was prompt, an estimated two minutes after the initial release. Both the alkylation and FCC unit, the CO boiler and control building sustained heavy structural damage. Four cooling towers and another control house were moderately damaged. Windows were broken 1½ miles away.</p>			

<u>DATE</u>	<u>LOCATION</u>	<u>LOSS AT TIME OF OCCURRENCE</u>	<u>LOSS TRENDED TO 1/1/84</u>
72. 8/30/79	Good Hope, LA	10,500,000	14,175,000
<p>A 514' general cargo ship heading down the Mississippi River veered out of control after its rudder stuck. At a refinery dock the freighter collided with a moored barge, which had just been loaded with 8,500 barrels of butane in six cylindrical pressure tanks, five of which ruptured. With release of the butane, fire engulfed the freighter, a tug boat and the dock. The barge drifted 3 miles downstream where it beached itself.</p>			
73. 9/1/79	Deer Park, TX	68,000,000	91,800,000
<p>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.</p> <p>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.</p> <p>The 120' diameter cone roof alcohol tank was about 1/3 full. It burned itself out in about 14 hours.</p>			
74. 11/15/79	Ponce, PR	10,000,000	13,500,000
<p>Failure of fractionation tower bottoms pump (probably the seal) in a refinery platforming unit spilled hydrocarbons which ignited.</p>			
75. 12/11/79	Ponce, PR	15,000,000	20,250,000
<p>The petrochemical complex which produced dicyclopentadiene, isoprene and piperylene had been shut down for 24 hours when a massive failure of a 13' diameter dimerizer vessel occurred. The 15 ton 1-1/8" 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 x 170 foot area. Blast damage covered a considerably larger area of approximately 240 x 400 feet in size.</p> <p>Damage to the isoprene plant is estimated at about \$5 million with \$10 million damage in the neighboring paraxylene plant.</p>			
76. 12/11/79	Geelong, Australia	11,236,000	15,169,000
<p>An inboard roller bearing failure in a reduced crude pump operating at 670°F in a refinery crude unit initiated the fractures of the motor shaft and pump bearing bracket. The pump casing then broke open allowing release of hot oil which auto-ignited. Since the pump was only equipped with manually operated suction valves which could not be reached and the column had no isolation valve, the column emptied to the fire.</p> <p>Access to the fire area was difficult and the table-top above the pump allowed the rapid spread of fire over a wide area eventually engulfing the entire pump house. Secondary pipe and flange failures contributed further fuel to the fire. The pump house, concrete structures, and fin-fans were destroyed in the fire which was extinguished by 12 hand lines and 15 portable monitor nozzles after 14 hours.</p>			

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DATE	LOCATION	LOSS AT TIME OF OCCURRENCE	LOSS TRENDED TO 1/1/84
77. 1/8/80	Avon, CA	15,000,000	18,300,000
Approximately fifty acts of vandalism to the control instruments of a refinery fluid coking unit occurred just prior to a labor strike. The company incurred an estimated \$69,000,000 business interruption loss in addition to the property damage figure shown.			
78. 1/20/80	Borger, TX	34,918,000	42,560,000
Few facts are known of this loss which apparently was initiated by a piping or vessel failure in a 16,800 barrel per day HF alkylation unit. Overpressures from a large vapor cloud explosion and the ensuing fire destroyed the alkylation unit and boiler plant and inflicted varying degrees of damage to the crude, FCC, gas converter, reformer and treating areas. The loss caused the entire refinery to be shut down until repairs could be made.			
79. 2/26/80	Brooks, AA	40,000,000	48,800,000
Rupture of a short section of buried 36" line between the flange and the valve body of a gate valve assembly was the source of an explosion and fire which destroyed much of a large natural gas transmission compressor station. At the time of the loss, throughput was 3.2 billion cubic feet per day, or 80% of capacity. The initial blast produced a small crater, thus exposing a 34" turbine discharge line which tied into the 36" line. Force of the escaping 950 psi gas twisted the 36" mainline upward and wrapped it around the 34" pipe which also ruptured. Ignition was prompt, and the gas jet was directed toward compressor buildings 250' distant and further where two out of three 20,000 horsepower turbine-driven compressors were destroyed and the third seriously damaged. The control building and meter house 600' from the fire source were destroyed. A building housing five reciprocating compressors was destroyed, as was the auxiliary shop. Automatic control facilities operated immediately after the first explosion to close all valves. Back-flow of gas between the line break and the next downstream valve 15 miles away burned off after about 3 hours.			
Note: This was the largest property damage loss ever sustained by the natural gas pipeline industry - probably by a factor of ten.			
80. 5/17/80	Deer Park, TX	18,000,000	21,960,000
Vibration from a pump bearing failure in a cumene section of a phenolacetone unit caused the pump seal to fail. The released flammable liquids and vapors ignited. Process pipes opened, adding fuel to the fire. Fin-fan coolers elevated above the pipe rack collapsed, as did one process column.			
81. 6/26/80	Sydney, Australia	17,977,000	21,932,000
An explosion in a hot oil furnace was followed by fire in a refinery butane deasphalting unit undergoing start-up following a 10 day shutdown.			
82. 7/23/80	Seadrift, TX	11,800,000	14,396,000
A new ethylene oxide unit had been shut down due to a direct lightning strike during a thunderstorm. While being brought back on stream, there was a decrease in RPM on the recycle compressor due to instrumentation problems. An ignition within the first reactor produced a detonation in the bottom of the reactor and in the 36" feed lines. Heat transfer fluid released by the explosion ignited and involved the primary reactor structure and adjacent equipment. Damage was localized but severe.			

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83. 10/21/80	New Castle, DE	45,750,000	55,815,000
Improper maintenance procedures during cleaning of a plugged recycle cooling line on a polypropylene reactor released hydrocarbons and polymer. Instead of removing only the motor operator of a 4" plug valve, the valve itself was accidentally removed. The release, at 150 psi, produced a vapor cloud which engulfed the finishing building. In about 6 minutes the vapors within the building ignited. The violent 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, depleting water pressure. 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. Twenty-one volunteer and paid fire departments and industrial fire brigades responded and fought the fire.			
84. 12/31/80	Corpus Christi, TX	17,000,000	20,740,000
A 1½-foot long crack developed in the laminated reactor of a hydrocracking unit while operating at 2500 psi. The unit depressured through the crack causing heavy fire damage during a 4½-hour period. Further details not yet available.			
85. 2/11/81	Chicago Heights, IL	14,000,000	15,260,000
While preparing a batch for a reactor in a resins manufacturing plant, steam was applied to a catalyst in a weigh tank because of sub-zero weather. An excess of heat caused the reaction to begin in the weigh tank. Since means for cooling the weigh tank were not available, the exothermic reaction caused the boil-over of the weigh tank's contents. Vapor cloud rapidly filled the one-story noncombustible building.			
Even though emergency shutdown procedures were immediately initiated, there was ignition of the vapors. The explosion disabled sprinkler protection. The ensuing fire, which was fought by public fire departments using relay pumping to supply monitor nozzles, destroyed the 7,000 square foot resins reactor area and an adjoining 6,000 square foot warehouse.			
86. 8/20/81	Shuaiba, Kuwait	50,000,000	54,500,000
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 fire fighting 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 fire fighting equipment were used to apply up to 11,000 US gpm of water and foam solution during the fire which lasted five days and twenty 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.			

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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 processing units at the 200,000 b/d refinery and petrochemical plant were effective. Damage was split 50-50 between liquid hydrocarbons and tanks and other equipment.

87. 1/20/82 Ft. McMurray, AA 21,000,000 21,530,000

A severe fire in a hydrogen compressor building in a Unifiner unit of an oil sands refinery reportedly started in a 1500 psi lube oil system. Fire fighting by the plant fire brigade, assisted by mutual aid fire brigades, was difficult because of -40°F temperatures. The building reportedly housed three centrifugal hydrogen recycle compressors, a centrifugal natural gas compressor and two 4000 horsepower reciprocating compressors. Further details are not available.

88. 2/9/82 Philadelphia, PA 25,000,000 25,625,000

One of three phenol units was destroyed and the other two damaged by an explosion and fire. In the process, cumene is oxidized with air to produce cumene hydroperoxide which is cleaved to phenol and acetone by acid catalysis. 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 rupture of the 25,000 gallon tank. Eventually two other process tanks and one containing fuel oil became involved.

The blast sheared off a 6" sprinkler riser; however, the plant's 1500 gpm steam and electric and two 2500 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 firemen and mutual aid workers from nearby chemical companies and refineries participated in controlling the fire.

* 89. 2/12/82 Nairobi, Kenya 11,500,000 11,673,000

A leaking gasoline tank at a government owned pipeline terminal ignited causing \$7,900,000 property damage and the loss of \$3,600,000 in gasolines. The fire spread to a second tank before being extinguished 54 hours later.

90. 4/18/82 Edmonton, AA 21,000,000 21,420,000

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 in the flow of ethylene but not before an estimated 450-11,000 pounds of gas had escaped.

* 91. 6/20/82 Pasadena, TX 10,000,000 10,200,000

A polypropylene silo elevated above the extruders was overfilled obstructing the vent. Nitrogen introduced to shake loose the powdered polypropylene blew the flexible connection loose from the bottom of the hopper. A dust explosion occurred

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followed by a fire. The hopper, exposed by fire, then exploded causing even more damage than the initiating incident.

92. 10/4/82 Freeport, TX 14,700,000 14,994,000

Failure of a 15 KV transformer containing 235 gallons of mineral oil was the probable cause of this explosion and fire in the electric power plant of a large petrochemical complex. With the ignition of the mineral oil, nearby heavily loaded cable trays ignited. These allowed the spread of fire. Heavy smoke evolved forcing the operators to evacuate the power block control room and making fire fighting by the plant fire brigade very difficult. After 6 hours the concrete roof of the control room collapsed.

* 93. 12/11/82 Taft, LA 11,405,000 11,519,000

A runaway reaction in a buried horizontal 60,000 gallon acrolein rundown tank was initiated when a power failure allowed temperature increases leading to uncatalyzed polymerization. The tank ruptured violently throwing tank and concrete fragments throughout the area.

* 94. 1/7/83 Newark, NJ 35,000,000 35,350,000

Pipeline gasoline was being received into a 42,000 barrel internal floating roof tank at a products terminal when an overflow occurred spilling about 1,300 barrels into the tank dike. A slight wind (1-5 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 neighboring properties. Although dikes contained the burning spill to the tank which 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 decision was made to let the fire burn itself out.

* 95. 4/7/83 Avon, CA 48,950,000 49,339,000

Rupture of a 12" recycle slurry line in a 47,000 barrel per day fluid catalytic cracking 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°-700°F. Shortly thereafter, a 600 psi steam line failed a few feet from the slurry line. It hampered fire fighting efforts due to extreme noise levels and the vaporizing of liquid hydrocarbons. Water spray of a pump alley and strong refinery water supplies allowed containment of the fire to a 70' x 140' area of the FCC unit. The FCC reactor, regenerator, fractionator, as well as related piping, instrumentation, and electrical equipment sustained severe damage.

* 96. 2/14/83 Bontang, East Kalimantan, Indonesia 50,000,000 50,500,000

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" blowdown line which 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 check list for start-up operations. Both trains were being started up following a shut down to allow tie-ins from two additional newly constructed LNG trains.

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*Indicates New Loss Incidents Reported as of the 1984 Seventh Edition.

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* 97.	5/26/83 Prudhoe Bay, AK	35,000,000	35,350,000
	A low-pressure NGL feed surge drum ruptured violently in this crude oil flow station, resulting in direct damage and subsequent fire damage to 1/3 of the enclosing module as well as moderate fire exposure damage to the exterior of surrounding structures within 100'. 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 time.		
* 98.	7/2/83 Fort McMurray, AA	12,150,000	12,272,000
	A fire involving the heat exchanger section in the gas oil hydro-treating section of an oil sands plant caused extensive damage. Further details are not available.		
* 99.	7/11/83 Port Arthur, TX	12,500,000	12,625,000
	A fire of unknown origin started in the mixing and blending section in the 3-story finishing building of this polyethylene bead manufacturing plant. The fire may have burnt for twenty minutes before discovery. It substantially damaged the building and blending and mixing operations on the upper floors. Extruders on the ground floor suffered limited fire and water damage. Damage to communicating laboratory, substation, bagging and warehouse buildings was very limited because of effective firewalls and firedoors.		

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* 100.	8/30/83 Milford Haven, Wales	15,000,000	15,150,000
	The most likely source of ignition of this 600,000 barrel floating roof tank fire was incandescent carbon particles discharged from the top of a 250 foot high refinery flare stack situated 350 feet from the tank. The 256' diameter x 66' high tank, which contained 348,000 barrels of North Sea Crude at the time of ignition, was arranged within a standard individual dike. It had a single mechanical seal and was equipped with a 12" high foam dam but no foam delivery lines or outlets. Reportedly, there were several cracks extending over 11" on the single plate floating roof. Inspections of the roof a few days before the fire revealed oil seepage onto the roof deck. There had been no oil transfer in the 24 hours preceding the fire.		
	When first noticed, fire involved about half of the tank roof area. It progressively spread to the entire surface. Cooling water streams were positioned to protect two 138' diameter 142,000 barrel fixed roof vacuum gas oil and fuel oil tanks situated 200 feet away. Oils were being pumped out of the three tanks in preparation for a major foam attack when, 12 hours into the fire, a violent boilover occurred in the crude tank. The ensuing fire covered 4 acres and destroyed or damaged much of the fire fighting equipment including two foam trucks. This was followed 2 hours later by a second less violent boilover. The major foam attack, which commenced 21 hours after ignition, continued for 14½ hours before extinguishment was complete. The crude tank was destroyed, two fixed roof tanks badly damaged, and 132,000 barrels of crude oil consumed.		
	This fire involved the use of 44 pumpers, 6 elevating platforms, and 14 foam trucks; from four nearby refineries and the public fire service. In addition, 66 commercial tankers and vehicles assisted in transporting the 201,599 U.S. gallons of 3% and 6% foam.		

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