



# Industrial Accidents Where Poor Human Procedures Were a Contributory Factor

## Key Findings From This Hexagon Study

Incidents Sampled	Total Fatalities	Total Injuries	Percentage of Affected Assets Not Owned and Operated in 2018	Total Reported Financial Costs (USD)
101	405	2163	38%	\$151,939,200,528
Incidents Date Range		Average Fatalities	Average Injuries	Average Reported Financial Costs (USD)
1983 to 2018		4	21	\$1,519,392,005
Average Reported Financial Costs (USD)				
Excluding Billion Dollar Incidents: BP Deepwater Horizon Oil Spill (2010), BP America Refinery Explosion (2005), Buncefield Fire (2005) and the Occidental Piper Alpha Explosion (1988)				
\$15,940,148				

## The Study in Detail Incidents sorted by date from the most recent downwards

Year	Incident	Human Factor	Fatalities	Injuries	Owned in 2018 and Operating	Reported Financial Costs (USD)
2018	<b>Husky Energy Refinery Explosion and Fire</b>	Lack of control and dynamic checklists with the human procedures.	0	36	Yes	\$53,000,000 (General Costs) \$27,000,000 (Plant Damage) \$83,150 (OSHA Fines) <b>Total: \$80,083,150</b>
2018	<b>Spooner Machine Explosion</b>	OSHA investigators determined an accumulation of hydrogen gas caused the explosion, and cited Spooner Machine for failing to develop and implement procedures to control the release of hydrogen gas during service and maintenance.	0	1	Yes	\$221,168 (OSHA Fines) <b>Total: \$221,168</b>

Year	Incident	Human Factor	Fatalities	Injuries	Owned in 2018 and Operating	Reported Financial Costs (USD)
2017	<b>Packaging Corporation of America Hot Work Explosion</b>	A hot work permit for welding was wrongly approved because flammable turpentine – that was left for months before the incident due to a lack of communication about who was responsible for its removal – was present inside a foul condensate tank which ignited due to the hot work welding sparks.	3	7	Yes	None Found
2017	<b>Tampa Electric / Gaffin Industrial Services Molten Slag Release</b>	Tampa Electric failed to follow energy control procedures while performing maintenance on equipment and Gaffin Industrial Services did not develop, document, and implement procedures for clearing clogs in a slag tank.	5	1	Yes	\$160,972 (OSHA Fines) <b>Total: \$160,972</b>
2016	<b>AirGas Facility Fatal Explosion</b>	Airgas never evaluated its process to identify and control process safety hazards, for example, although the company recognized the potential for an explosive nitrous oxide decomposition, Airgas provided no effective safeguards and simply instructed the operators to stop the pump if there was a “marked change in sound level”.	1	0	No (Plant Destroyed in Incident)	None Found (OSHA Fines Deleted)
2016	<b>Poet Biorefining-Hudson / Bilfinger-Westcon Fire</b>	Bilfinger-Westcon conducted welding operations in an area where flammable liquids could be present and Poet Biorefining-Hudson failed to implement written procedures to conduct shutdown activities including verifying the process piping did not contain ethanol and didn’t ensure safe work practices including controlling the entrance, presence and exit of contract workers within the process area.	1	0	Yes	\$99,768 (OSHA Fines) <b>Total: \$99,768</b>
2016	<b>ExxonMobil Refinery Chemical Release and Fire</b>	When alkylation unit operators encountered a malfunctioning gearbox on a plug valve, it was an accepted practice for the operator to remove the gearbox to open or close the valve with a pipe wrench, unfortunately the baton rouge refinery management did not, however, provide alkylation unit workers performing this operations activity with a written procedure or training on safe gearbox removal from plug valves and its associated hazards.	0	4	Yes	\$164,773 (OSHA Fines) <b>Total: \$164,773</b>
2016	<b>MGPI Processing, Inc. Toxic Chemical Release</b>	Each step in the inconsistent chemical unloading procedure which led to the incident was not recorded and monitored and operators indicated that the procedure did not state that a correct connection be verified.	0	140	Yes	None Found
2016	<b>University of Hawaii Laboratory Explosion</b>	According to HIOSH, the University of Hawaii failed to reduce employee exposure to potential explosion and fire hazards, didn’t ensure safety practices were followed, failed to perform periodic inspections to identify hazards, and also failed to make use of standard operating procedures.	0	1	Yes	\$69,000 (HIOSH Fines) <b>Total: \$69,000</b>
2015	<b>ExxonMobil Refinery Explosion</b>	ExxonMobil relied on indirect operating parameters to measure critical safeguards for the safe park mode of operation and the relied-upon operating parameters did not signify that the FCC unit was in a dangerous condition before the incident, safe park procedure development and improved measurement and control of critical process conditions could have prevented this incident.	0	4	No (Refinery Sold to PBF Energy in 2015)	\$566,600 (Cal/OSHA Fines) <b>Total: \$566,600</b>
2015	<b>Ultratec Special Effects Explosion</b>	According to OSHA, the process hazard analysis was not updated, as it was supposed to be every five years, clear safety instructions were not posted for each process (multiple violations) and a compliance evaluation had not been conducted as often as required.	2	0	Yes	\$52,977 (OSHA Fines) <b>Total: \$52,977</b>
2014	<b>DuPont La Porte Facility Toxic Chemical Release</b>	A series of shift communication mistakes – that began five days before the incident – eventually led to the release of nearly 24,000 pounds of methyl mercaptan, a toxic chemical.	4	1	No (Plant Closed in 2016)	\$3,100,000 (EPA Fines) \$273,000 (OSHA Fines) <b>Total: \$3,373,000</b>
2014	<b>Haverhill Chemicals Reactor Drain Fatal Chemical Exposure</b>	The company failed to develop procedures for the normal and emergency shutdown of the Bisphenol A reactor and didn’t develop written procedures to maintain equipment used to process chemicals during maintenance.	1	0	No (Plant Sold to ALTIVIA Petrochemicals in 2015)	\$134,000 (OSHA Fines) <b>Total: \$134,000</b>

Year	Incident	Human Factor	Fatalities	Injuries	Owned in 2018 and Operating	Reported Financial Costs (USD)
2014	<b>Tesoro Martinez Sulfuric Acid Spill</b>	The minimization of the seriousness of process safety incidents, failure to learn from past incidents at the refinery and implement important safety lessons, taking safer sulfuric acid sampling equipment out of service, weak management commitment to robust practices and procedures, and tolerance of worker exposure to unsafe conditions, were causal to both the February and March 2014 sulfuric acid incidents.	0	4	Yes	\$43,400 (Cal/OSHA Fines) <b>Total: \$43,400</b>
2014	<b>U.S. Steel Fairfield Explosion</b>	A procedure was not developed or used to allow workers to operate the valves on a furnace while it was in operation and to control the hazardous energy.	2	1	Yes	\$107,990 (OSHA Fines) <b>Total: \$107,990</b>
2013	<b>Fox Valley Systems Explosion</b>	An OSHA inspection found that Fox Valley Systems failed to develop and implement written, safe operating and mechanical integrity procedures, and failed to conduct inspections and tests on process equipment.	0	3	Yes	\$262,000 (OSHA Fines) <b>Total: \$262,000</b>
2013	<b>IVEX Protective Packaging Explosion</b>	According to OSHA, IVEX Protective Packaging failed to have detailed operating procedures, provide operator and maintenance technician training and develop an inspection and testing program.	0	3	Yes	\$128,700 (OSHA Fines) <b>Total: \$128,700</b>
2013	<b>KiwiRail Train Derailment</b>	Employees were not given instructions to follow and did not record their progress so when an overnight shift change took place, the task of fitting a brake component was omitted.	0	4	Yes	None Found
2013	<b>Williams Olefins Plant Explosion and Fire</b>	Prior to manipulating hazardous valves in the field, Williams did not conduct a hazard analysis and develop written procedures for the operations personnel.	2	167	No (Plant Sold to NOVA Chemicals in 2017)	\$33,992,957.32 (Legal Costs) \$36,000 (OSHA Fines) <b>Total: \$34,028,957.32</b>
2012	<b>Chevron Refinery Fire</b>	The 52-inch pipe component which failed in 2012 was never inspected again after an inspector identified corrosion in 2002.	0	6	Yes	\$20,000,000 (Plant Upgrades) \$5,000,000 (Legal) \$1,010,000 (OSHA) \$200,000 (Donation) <b>Total: \$26,210,000</b>
2012	<b>Wynnewood Refining Co. LLC Boiler Explosion</b>	Wynnewood did not have operating procedures which addressed consequences of deviation from operating limits (including steps to avoid deviation from operating limits), provide training at least every three years on the practice of igniting boiler burners, establish and implement written procedures for testing and inspecting the shutdown and gas train interlocks for the boiler, and implement a management of change procedure when modifying boiler operating procedures.	2	0	Yes	\$99,000 (OSHA Fines) \$86,000 (EPA Fines) <b>Total: \$185,000</b>
2011	<b>Bostik Middleton Plant Explosion</b>	Bostik did not address human factors such as operator error, communication between shift changes and employee fatigue from excessive overtime.	0	4	Yes	\$600,000 (OSHA Fines) <b>Total: \$600,000</b>



Year	Incident	Human Factor	Fatalities	Injuries	Owned in 2018 and Operating	Reported Financial Costs (USD)
2011	<b>Donaldson Enterprises, Inc. Fatal Fireworks Disassembly Explosion and Fire</b>	The activity hazard analysis and procedures failed to identify and control the key explosive hazards involved in this process.	5	1	No (Facility was Leased)	\$1,500,000 (Legal) \$415,200 (HIOSH Fines) <b>Total: \$1,915,200</b>
2011	<b>Hoeganaes Corporation Fatal Flash Fires</b>	There was tons of accumulated iron dust across the facility which was partly due to a lack of housekeeping procedures.	5	3	Yes	\$48,492,000 (Legal) \$129,200 (TOSHA) \$129,000 (OSHA) <b>Total: \$48,750,200</b>
2011	<b>Honeywell International Vapor Release</b>	Honeywell failed to have clear written operating instructions for processes such as unloading hydrogen fluoride into storage tanks and switching storage tanks, failed to address human factors in relation to remote operating valves on the hydrogen fluoride storage tanks, failed to establish written procedures to maintain the integrity of process equipment, failing to implement written emergency operating procedures for emptying hydrogen fluoride tanks, failed to perform appropriate checks and inspections to ensure equipment was properly installed, and failed to establish and implement written procedures to manage changes to process chemicals, equipment and procedures.	0	0	Yes	\$119,000 (OSHA Fines) <b>Total: \$119,000</b>
2010	<b>AL Solutions Fatal Dust Explosion</b>	In the days before the explosion the maintenance performed on the blender and paddle only temporarily addressed the problems caused by the metal-to-metal contact and as a result the blender was not repaired or replaced to avoid exposing combustible metal dusts to sparks or heat produced by the mechanical impact from the paddle.	3	1	Yes	\$17,500,000 (Legal Costs) \$100,000 (EPA Fines) \$97,000 (OSHA Fines) <b>Total: \$17,697,000</b>
2010	<b>BP Deepwater Horizon Oil Spill</b>	No evidence that BP or Halliburton ever shared the cement stability results or the OptiCem reports – showing gas flow potential – with Transocean personnel on the Deepwater Horizon or in the Houston office.	11	17	No (Drilling Rig Destroyed in Incident)	\$144,890,000,000 (Full Estimated Costs) <b>Total: \$144,890,000,000</b>
2010	<b>DuPont Corporation Toxic Chemical Releases</b>	Phosgene hoses were meant to be changed every 30 days but it was found on the date of the accident they had not been changed in over 7 months, this was due to a lack of enforced standard operating procedures.	1	2	Yes	\$43,000 (OSHA Fines) <b>Total: \$43,000</b>
2010	<b>E. I. DuPont De Nemours Co. Fatal Hot Work Explosion</b>	Technicians did not test for a flammable atmosphere inside tanks before contractors conducted dangerous hot work.	1	1	Yes	\$116,940 (OSHA Fines) <b>Total: \$116,940</b>
2010	<b>Kleen Energy Natural Gas Explosion</b>	Some contractors were instructed to continue working inside the dangerous building during the natural gas blow activities.	6	50	Yes	\$16,600,000 (OSHA Fines) <b>Total: \$16,600,000</b>
2010	<b>Millard Refrigerated Services Ammonia Release</b>	Without guidance, an operator manually cleared an alarm in the system, which resulted in an interruption of a defrost cycle that was in progress for a blast freezer evaporator.	0	153	Yes	\$3,000,000 (EPA Fines) \$52,500 (OSHA Fines) <b>Total: \$3,052,500</b>
2010	<b>Tesoro Refinery Fatal Explosion and Fire</b>	There was an overall failure to provide controlled written procedures to operations personnel and Tesoro was not aware of the severe HTHA damage in the B and E heat exchangers because it never performed any type of HTHA examination of the heat exchangers.	7	0	Yes	\$39,000,000 (Legal Costs) <b>Total: \$39,000,000</b>
2010	<b>WRR Environmental Services Explosion</b>	According to OSHA, WRR Environmental Services failed to implement process hazard analyses, operating procedures and training, failed to perform pre-startup safety reviews and inspections and tests on process equipment, failed to implement change management procedures and failed to conduct incident investigations.	0	0	Yes	\$340,000 (OSHA Fines) <b>Total: \$340,000</b>
2009	<b>A.V. Thomas Produce Fuel Tank Explosion</b>	The facility had no formal hot work program, and no permit was issued for the hot work being performed, also no combustible gas testing was performed prior to commencement of the hot work; the company did not have a policy that required it and in addition, many workers were mono-lingual Spanish speakers and had not been trained on safe hot work procedures or on the proper use of gas detectors in their native language.	0	2	Yes	None Found

Year	Incident	Human Factor	Fatalities	Injuries	Owned in 2018 and Operating	Reported Financial Costs (USD)
2009	<b>ConAgra Natural Gas Explosion and Ammonia Release</b>	There wasn't a process to ensure that natural gas detectors were used to test the atmosphere, instead workers wrongly trusted their sense of smell.	4	67	No (Plant Closed in 2010)	\$108,900,000 (Legal Costs) \$14,600,000 (Legal Costs) \$106,440 (OSHA Fines) <b>Total: \$123,606,440</b>
2009	<b>Caribbean Petroleum Refining Tank Explosion and Fire</b>	The facility lacked standard operating procedures addressing the influence of valve cracking on calculating the tank fill time which led to a 5-million gallon above ground storage tank (AST) overflowing.	0	0	No (Filed for Bankruptcy in 2010 Due to Incident)	\$8,200,000 (EPA Bankruptcy Settlement) \$5,000,000 (Damages to Nearby Military Facility) <b>Total: \$13,200,000</b>
2009	<b>NDK Crystal Inc. Explosion With Offsite Fatality</b>	NDK has no documentation of any internal inspections of Vessel No. 2 throughout its six-year service life, other than regular visual inspections of the top portion of the vessel between runs, NDK did not have a scheduled inspection program for entire length of the vessel interior.	1	1	No (Plant Destroyed in Incident)	\$510,000 (OSHA Fines) \$49,000 (IEPA Fines) <b>Total: \$559,000</b>
2009	<b>Silver Eagle Refinery Flash Fire and Explosion and Catastrophic Pipe Explosion</b>	The component which failed in the ruptured pipe which caused a massive explosion had no record of ever being inspected for corrosion as it thinned over the years.	0	4	Yes	\$325,000 (Legal) \$135,500 (OSHA) \$6,000 (OSHA) <b>Total: \$466,500</b>
2009	<b>TEPPCO Partners Gasoline Storage Tank Explosion</b>	The hot work permit indicated that gas testing occurred at 07:00, the start of the work shift, however, no documentation exists indicating that gas testing was conducted after the workers returned from lunch or when they started the hot work activities just prior to the explosion at approximately 14:00.	3	0	No (Sold to Enterprise Products in 2009)	\$200,000 (PHMSA Fines) <b>Total: \$200,000</b>
2009	<b>Veolia Environmental Services Flammable Vapor Explosion and Fire</b>	The company failed to conduct compliance audits every three years to ensure that policies and procedures were in place for the handling of flammable liquid and there were also training deficiencies, inadequate testing and inspections of piping and processes, a lack of written standards for operating procedures, maintaining mechanical integrity of equipment, and other items involving process safety.	0	4	Yes	\$27,000,000 (Lost Production, Property Damage, and Business Disruption) \$35,000 (OSHA Fines) <b>Total: \$27,035,000</b>
2008	<b>Allied Terminals Fertilizer Tank Collapse</b>	Allied had no safety procedures or policies for work on or around tanks that were being filled for the first time following major modifications and directed contractors to seal leaking rivets while Tank 201 was being filled to the calculated maximum liquid level for the first time.	0	2	No (Sold to Kinder Morgan in 2013)	\$55,626 (EPA Fines) <b>Total: \$55,626</b>
2008	<b>Bayer CropScience Pesticide Waste Tank Explosion</b>	Operators were using an unreviewed, unapproved draft SOP and these procedures were overly complex and not readily available.	2	8	Yes	\$25,000,000 (Plant Redesign) \$5,657,000 (EPA Fines) \$143,000 (OSHA Fines) \$37,000 (Property Damage Claims) <b>Total: \$30,837,000</b>
2008	<b>EMC Used Oil Corporation Oil Tanker Explosion</b>	The surviving worker stated that the contractors did not perform combustible gas monitoring and relied upon the host company to assure that tanks were safe for hot work, however, EMC indicated that it relied on contractors to monitor for gas - although the company owned a multiple gas detector - it was used only for confined space entry and EMC did not have a formal hot work permitting or authorization system.	1	1	Yes	None Found
2008	<b>Goodyear Heat Exchanger Rupture</b>	Evidence of breakdowns in both the work order and lockout/tagout procedures contributed to the incident.	1	7	Yes	\$43,000 (OSHA Fines) <b>Total: \$43,000</b>
2008	<b>Imperial Sugar Company Dust Explosion and Fire</b>	Complacency led to a lack of regular procedures to clean up tons of spilled sugar which led to a horrific combustible dust explosion.	14	38	Yes	\$345,000,000 (Legal Costs) \$6,050,000 (OSHA Fines) <b>Total: \$351,050,000</b>

Year	Incident	Human Factor	Fatalities	Injuries	Owned in 2018 and Operating	Reported Financial Costs (USD)
2008	<b>INDSPEC Chemical Corporation Oleum Release</b>	The facility never included information on the emergency power supply in piping and instrumentation diagrams and written operating procedures and Process Hazard Analysis teams were therefore unable to evaluate the consequences of emergency power supply use.	0	1	No (Plant Closed in 2017)	\$40,500 (OSHA Fines) <b>Total: \$40,500</b>
2008	<b>International Paper Vicksburg Mill Explosion</b>	They didn't have safe procedures to start up the recovery boiler when the primary power boiler was offline and they didn't have written procedures to determine that an adequate amount of odorant was being added to the natural gas supply line coming into the power plant.	1	22	Yes	\$14,000 (OSHA Fines) <b>Total: \$14,000</b>
2008	<b>MAR Oil Storage Tanks Explosion</b>	MAR Oil lacked a formal hot work program that required the hot work be identified in a written permit and be authorized by a person responsible for hot work management and the company had no formal program to select or oversee contractors, and the two contractors lacked documented training on safe hot work practices.	2	0	No (Asset Destroyed in Incident)	None Found
2008	<b>Packaging Corporation Storage Tank Explosion</b>	At the time of the incident, PCA supervisors and workers were unaware of the risks of flammable gas production from anaerobic bacteria growth and PCA did not perform a hazard analysis or recognize fiber waste tanks as potentially hazardous, combustible gas monitoring was also not required for the work.	3	1	Yes	\$94,000 (OSHA Fines) <b>Total: \$94,000</b>
2008	<b>Philip Services Corporation Waste Oil Storage Tank Explosion</b>	Contractors were not authorized to weld within the dike area surrounding the tank, a hot work permit had not been issued for the welding, and combustible gas monitoring was not conducted.	1	3	No	None Found
2007	<b>ArcelorMittal Plate Furnace Explosion</b>	There were no written procedures for clearing a blocked tap hole and there were no written procedures for what to do when there was significant water in the furnace.	2	1	Yes	\$11,000 (OSHA Fines) <b>Total: \$11,000</b>
2007	<b>Little General Store Propane Explosion</b>	No standard operating procedures led to the removal of a plug without checking first for a propane leak.	4	6	No (Store Destroyed in Incident)	\$120,000,000 (Legal Costs) <b>Total: \$120,000,000</b>
2007	<b>Mantrose-Haeuser Co. Inc. Amputation</b>	There was a lack of lockout/tagout devices and training, a lack of written procedures, training and other elements of the plant's process safety management program.	0	1	Yes	\$113,500 (OSHA Fines) \$21,500 (OSHA Fines) <b>Total: \$135,000</b>
2007	<b>Valero Refinery Propane Fire</b>	Had no formal procedure in place to identify, review, and freeze protect dead-legs or infrequently used piping and equipment, such as the propane mix control station.	0	4	Yes	\$50,000,000 (General Losses) <b>Total: \$50,000,000</b>
2006	<b>Bethune Point Wastewater Plant Explosion</b>	No procedures for hot work and inspections of critical safety equipment.	2	1	Yes	None Found
2006	<b>CAI / Arnel Chemical Plant Explosion</b>	A production manager forgot to turn off a steam heating valve due to the lack of written procedures and checklists.	0	10	No (Plant Destroyed in Incident)	\$7,000,000 (Legal Costs) \$1,400,000 (EPA Fines) <b>Total: \$8,400,000</b>
2006	<b>Jamegy Inc. Mill Tank Fire</b>	A lack of proper confined space permits and lockout-tagout (LOTO) procedures led to a supervisor entering a dangerous mill tank which ignited, leading to a fatal injury.	1	0	Yes	\$5,100 (OSHA Fines) <b>Total: \$5,100</b>
2006	<b>Partridge Raleigh Oilfield Explosion and Fire</b>	If hot work procedures and permits were mandatory, the hydrocarbon liquid and/or vapor inside the tanks would probably have been identified and measures would likely have been taken to remove or isolate the hazard.	3	1	No (Asset Destroyed in Incident)	\$40,300 (OSHA Fines) <b>Total: \$40,300</b>
2006	<b>Synthron Chemical Explosion</b>	After receiving an increased batch order, managers changed the process to complete it without understanding the high possibility of an adverse chemical reaction the batch increase would cause.	1	14	No (Plant Destroyed in Incident)	\$379,050 (NCDOL Fines) \$189,525 (OSHA Fines) <b>Total: \$568,575</b>
2005	<b>Acetylene Service Company Gas Explosion</b>	Operators had no written guidance on the correct operation of the recycle system or on the consequences of deviation from the intended operating sequence.	3	8	No (Warehouse Destroyed in Incident)	\$11,700,000 (Legal Costs) <b>Total: \$11,700,000</b>

Year	Incident	Human Factor	Fatalities	Injuries	Owned in 2018 and Operating	Reported Financial Costs (USD)
2005	<b>Arboris Explosion and Fire</b>	An investigation by OSHA found that Arboris failed to develop operational procedures to maintain the ongoing integrity of equipment, develop procedures to prevent inadvertent start-up or release of stored energy, document inspections and maintenance, follow standard operating procedures, review operating procedures annually, develop procedures for starting up the system after a turnaround, and provide clear instructions to employees during service and maintenance.	0	4	Yes	\$135,135 (OSHA Fines) <b>Total: \$135,135</b>
2005	<b>BP America Refinery Explosion</b>	Supervisors and operators poorly communicated critical information regarding the start-up procedure during the shift turnover and BP did not have a shift turnover communication requirement for its operations staff.	15	180	Yes	\$2,000,000,000 (Legal Costs) \$180,000,000 (EPA Fines) \$63,627,000 (OSHA Fines) <b>Total: \$2,243,627,000</b>
2005	<b>Buncefield Fire</b>	Confusion arose because of deficiencies in the shift handover procedures and the overlapping screens on the ATG system.	0	43	Yes	\$1,792,380,600 (General Costs – July 15 <sup>th</sup> 2008 GBP to USD Exchange Rate: 894,000,000 x 2.0049) \$12,938,752 (Legal Costs – July 16 <sup>th</sup> 2010 GBP to USD Exchange Rate: 8,433,000 x 1.5343) <b>Total: \$1,805,319,352</b>
2005	<b>Formosa Plastics Propylene Explosion</b>	Hazard reviews did not fully address protection of specific process equipment from vehicle impact or the use of remotely actuated valves to control a catastrophic release.	0	16	Yes	\$148,000 (OSHA Fines) <b>Total: \$148,000</b>
2005	<b>Kern Oil and Refining Explosion</b>	According to OSHA, Kern Oil and Refining failed to develop and implement temporary operation procedures for removing filter screens and steaming out the crude unit's prefractionator bottoms pump. A temporary operating procedure is required to address an explosion hazard such as water condensing inside the flexible steam line and being introduced into the pump containing hot crude oil.	1	2	Yes	\$33,795 (OSHA Fines) <b>Total: \$33,795</b>
2005	<b>Valero Refinery Asphyxiation Incident</b>	The paper Permit to Work document did not warn the shift crew that the reactor was full of nitrogen. Instead, "Nitrogen Purge or Inerted" was stated as "N/A".	2	0	No (Refinery Sold to PBF Energy in 2010)	\$107,500 (OSHA Fines) <b>Total: \$107,500</b>
2004	<b>Giant Industries Refinery Explosions and Fire</b>	The facility lacked procedures to verify that the pump had been isolated, depressurized and drained and also an MOC hazard analysis was not conducted and if it was it could have revealed the potential for the valve wrench to be oriented in the wrong direction.	0	6	No (Refinery Sold to Western Refining in 2006)	\$13,000,000 (Refinery Damage) \$850,000 (EPA Fines) <b>Total: \$13,850,000</b>
2004	<b>Formosa Plastics Vinyl Chloride Explosion</b>	Systems and procedures were insufficient to minimize the potential for human error.	5	2	Yes	\$12,800,000 (EPA Fines) \$300,000 (OSHA Fines) <b>Total: \$13,100,000</b>
2004	<b>Marcus Oil and Chemical Tank Explosion</b>	Marcus Oil did not use a qualified welder or proper welding procedure to reweld the plate on the vessel heads and install the steam pipe nozzles in the shells and personnel also acknowledged that they did not hydrostatically pressure test the vessels after.	0	3	No (Plant Assets Auctioned in 2018)	\$107,250 (OSHA Fines) <b>Total: \$107,250</b>
2004	<b>MFG Chemical Inc. Toxic Gas Release</b>	MFG did not develop the comprehensive process hazards analysis, pre-startup review, and emergency response elements required by the OSHA PSM standard and the EPA Risk Management Program regulation.	0	155	Yes	\$270,000 (EPA Fines) <b>Total: \$270,000</b>
2004	<b>Sterigenics Ethylene Oxide Explosion</b>	No formal human processes led to an incorrect gas wash override.	0	4	Yes	\$36,000 (OSHA Fines) <b>Total: \$36,000</b>

Year	Incident	Human Factor	Fatalities	Injuries	Owned in 2018 and Operating	Reported Financial Costs (USD)
2003	<b>BLSR Operating Ltd. Vapor Cloud Fire</b>	BLSR management had no written procedures for truck unloading, operation of systems, or emergency response and employees learned their tasks exclusively through on-the-job training by BLSR management and experienced workers and - as a result - BLSR relied on the truck drivers to decide which of the two unloading systems to use.	3	4	Yes	\$30,650 (OSHA Fines) <b>Total: \$30,650</b>
2003	<b>Catalyst Systems Inc. Reactive Chemical Explosion</b>	There were no written operating procedures for drying Benzoyl Peroxide using the vacuum dryer; management provided only verbal instructions to the operators.	0	1	No (Plant Closed)	\$105,000 (OSHA Fines) <b>Total: \$105,000</b>
2003	<b>CTA Acoustics Dust Explosion and Fire</b>	Although management was aware of dust explosion hazards associated with the materials being used, dust had accumulated in dangerous amounts throughout the production areas, in vent ducting, and in dust collector housings, due to inadequate housekeeping and maintenance.	7	37	Yes	\$28,000 (OSHA Fines) <b>Total: \$28,000</b>
2003	<b>D.D. Williamson &amp; Co. Catastrophic Vessel Failure</b>	DDW did not have adequate operating procedures or adequate training programs to ensure that operators were aware of the risks of allowing the spray dryer feed tanks to overheat and knew how to respond appropriately.	1	0	Yes	\$10,000 (OSHA Fines) <b>Total: \$10,000</b>
2003	<b>DPC Enterprises Glendale Chlorine Release</b>	DPC's corporate hazard assessment process did not identify or address the consequences of failure to follow the bleach manufacturing SOP, including potential off-site consequences and Compliance with the scrubber procedure was not enforced, further weakening an already inadequate safeguard.	0	14	Yes	None Found
2003	<b>Hayes Lemmerz Dust Explosions and Fire</b>	The dust collector, was not been adequately vented or cleaned and Hayes did not follow management of change procedures that might have identified the dust explosion hazard.	1	6	No (Plant Closed in 2006)	\$42,000 (OSHA Fines) <b>Total: \$42,000</b>
2003	<b>Honeywell Chemical Incidents</b>	Hazard analyses did not ensure a review of all equipment, procedures, and likely scenarios, nonroutine situations were not always recognized and reviewed to ensure that work could proceed safely and work practices at the plant did not always strictly follow written operating procedures.	1	9	Yes	\$8,000,000 (Criminal Fine) \$2,000,000 (Community Restitution) \$2,000,000 (Legal Settlement) <b>Total: \$12,000,000</b>
2003	<b>Isotec/Sigma Aldrich Nitric Oxide Explosion</b>	There was no written documentation that action had been taken to minimize the explosive potential of the Nitric Oxide system and although there were two previous Nitric Oxide distillation unit failures the investigation records were incomplete and there was no record of the cause of the incidents and no documentation of corrective actions to prevent recurrence.	0	1	Yes	None Found
2003	<b>Technic Inc. Ventilation System Explosion</b>	Technic did not conduct a process safety review to identify and evaluate the hazards associated with installing a vent collection system to handle the exhaust from multiple processes and did not identify and evaluate the hazards created by changes to facility processes and equipment (management of change).	0	19	Yes	None Found
2002	<b>DPC Enterprises Festus Chlorine Release</b>	The DPC testing and inspection program did not include procedures to ensure that the process emergency shutdown system would operate as designed.	0	66	Yes	None Found
2002	<b>Environmental Enterprises Hydrogen Sulfide Release</b>	At the time of the incident, the facility had no written procedures for operating the wastewater treatment area. Although each waste batch was unique and required customized treatment protocols, EEI relied on the knowledge of plant personnel with many years' experience in waste treatment to take appropriate actions.	0	1	Yes	\$5,100 (OSHRC Fines) <b>Total \$5,100</b>
2002	<b>First Chemical Corp. Reactive Chemical Explosion</b>	The plant did not have adequate systems to warn operations personnel of unexpected temperature increases.	0	3	No (Plant Sold to DuPont in 2002)	\$731,000 (EPA Fines) <b>Total: \$731,000</b>



Year	Incident	Human Factor	Fatalities	Injuries	Owned in 2018 and Operating	Reported Financial Costs (USD)
2002	<b>Kaltech Industries Waste Mixing Explosion</b>	The employees who pumped the contents from the carboys prior to the incident incorrectly assumed the identity of the materials as there was no hazard communication program, written or otherwise.	0	36	No (Plant Closed)	\$88,000 (OSHA Fines) <b>Total: \$88,000</b>
2002	<b>Rouse Polymeric Rubber Dust Explosion</b>	Design and procedures for operating the gas-fired dryers and dust collector were inadequate, as was housekeeping, and that plant personnel lacked awareness of the hazards of accumulated layers of combustible rubber dust and investigators also linked ineffective management of change to the incident.	5	7	No (Plant Destroyed in Incident)	\$187,680 (OSHA Fines) <b>Total: \$187,680</b>
2001	<b>BP Amoco Thermal Decomposition Incident</b>	Equipment opening procedures did not specify what actions to take when safety precautions could not be met and revisions to operating procedures were not subjected to management of change reviews to evaluate safety effects.	3	0	No (Sold to Solvay in 2001)	\$119,000 (OSHA Fines) <b>Total: \$119,000</b>
2000	<b>Electronic Recovery Specialist Inc. Explosion</b>	The company failed to establish written procedures and didn't train employees in safe operating procedures.	1	5	No (Plant Closed)	\$99,000 (OSHA Fines) <b>Total: \$99,000</b>
2000	<b>Lomac Explosion</b>	As a result of a MIOSHA compliance inspection in 1993, Lomac developed a "Process Safety Management Plan" which contained procedures for operating processes covered by the MIOSHA Process Safety Management of Highly Hazardous Chemicals (PSM) standard and each section in that plan describes activities for managing process hazards in a particular area, however, Lomac did not consistently follow the requirements developed in their own plan.	0	10	No (Plant Closed)	\$3,000,000 (MIOSHA Fines) <b>Total: \$3,000,000</b>
1999	<b>Ford River Rouge Power Plant Secondary Coal Dust Explosion</b>	Housekeeping to minimize coal dust accumulations was inadequate.	6	36	No (Power Plant Destroyed in Incident)	\$7,000,000 (MIOSHA Fines) <b>Total: \$7,000,000</b>
1999	<b>Jahn Foundry Resin Dust Explosion</b>	There was inadequate housekeeping to minimize resin accumulation in the vent ducting.	3	9	No (Plant Destroyed in Incident)	\$35,000,000 (Legal Costs) \$115,500 (OSHA Fines) <b>Total: \$35,115,500</b>
1998	<b>Esso Longford Gas Explosion</b>	The events leading up to the accident disclosed a number of instances where operators failed to adhere to basic operating practices and some of these practices were written procedures, for example, those for shift handover and operator log entries.	2	8	Yes	\$24,255,287 (Legal Costs – November 8 <sup>th</sup> 2004 USD to AUD Exchange Rate: 32,000,000 / 1.3193) \$1,011,020 (Legal Costs – July 30 <sup>th</sup> 2001 USD to AUD Exchange Rate: 2,000,000 / 1.9782) \$909,695 (Legal Costs – June 23 <sup>rd</sup> 2003 USD to AUD Exchange Rate: 1,370,000 / 1.506) \$531,143 (Legal Costs – December 3 <sup>rd</sup> 2001 USD to AUD Exchange Rate: 1,025,000 / 1.9298) <b>Total: \$26,707,145</b>
1997	<b>Bartlo Packaging Incorporated (BPS) Explosion</b>	An EPA/OSHA Joint Chemical Accident Investigation Report found that BPS did not have standard operating procedures for material storage and handling. EPA/OSHA also suggested that standard operating procedures could have prevented BPS from placing a thermally unstable substance next to a heat source, in this case, the compressor header pipe.	3	17	Yes	None Found
1994	<b>Shell Chemical Belpre Explosion</b>	A technician acting alone, allowed the chemical reaction - which led to the explosion - to continue even when the wrong mixture of chemicals was detected in a reactor.	3	0	No (Sold to Ripplewood Holdings LLC in 2000)	\$275,000,000 (Damages) \$7,200,000 (Legal Costs) \$3,017,000 (OSHA Fines) <b>Total: \$285,217,000</b>

Year	Incident	Human Factor	Fatalities	Injuries	Owned in 2018 and Operating	Reported Financial Costs (USD)
1992	<b>Arcadian Lake Charles Explosion</b>	A carbamate leak – which corroded the containment vessel involved in the accident - went undetected because weep holes in the containment vessel were not adequately checked to detect ammonia and carbon dioxide coming out ahead of the carbamate.	0	60	No (Plant Destroyed in Incident)	\$5,085,000 (OSHA Fines) <b>Total: \$5,085,000</b>
1992	<b>Hickson &amp; Welch Fire</b>	Multiple failures in maintenance and Permit to Work procedures.	5	200	No (Plant Sold to Arch Chemicals in 2000)	\$5,130,000 (General Costs – September 21 <sup>st</sup> 1992 GBP to USD Exchange Rate: 3,000,000 x 1.71) <b>Total: \$5,130,000</b>
1991	<b>CITGO Petroleum Explosion</b>	The blast occurred as a catalytic cracking unit was being restarted after a seven-week shutdown for maintenance and during the start-up, a drainage valve at the bottom of a big pressure vessel was improperly closed, allowing water to accumulate inside.	6	11	Yes	\$5,800,000 (OSHA Fines) \$200,000 (Goodwill Donation) <b>Total: \$6,000,000</b>
1991	<b>Continental Express Aircraft Crash</b>	The critical error of not replacing a row of fasteners might have been detected if shift handover procedures had been properly followed by outgoing and incoming shift workers.	14	0	No (Aircraft Destroyed in Incident)	None Found
1990	<b>ARCO Channelview Explosion</b>	Since the wastewater tank – that exploded - was not considered to be part of the operating plant no proper hazard analysis was conducted and with lack of understanding of the whole process, a series of bad decisions were made such as no management of change review for any decision, and no pre-start-up safety review.	17	5	No (Sold to Lyondell Petrochemical Co. in 1998)	\$100,000,000 (Plant Damages) \$3,481,300 (OSHA Fines) <b>Total: \$103,481,000</b>
1989	<b>Phillips Disaster of 1989</b>	An effective Permit to Work (PTW) system for both company employees and contractors was not enforced by the company and both the company and industry safety regulations required isolation by means of a double-block system or the use of blind flange, however, at a plant level a procedure had been adopted which did not comply with this.	23	300	Yes	\$4,000,000 (OSHA Fines) \$100,000 (OSHA Fines) <b>Total: \$4,100,00</b>
1988	<b>Occidental Piper Alpha Explosion</b>	Details about the replacement of a pressure safety valve with a blank flange – and instructions not to use it – failed to be communicated during the shift handover.	167	61	No (Platform Destroyed in Incident)	\$1,470,000,000 (General Costs) <b>Total: \$1,470,000,000</b>
1983	<b>Sellafield Beach Incident</b>	Highly radioactive waste liquor was accidentally discharged to sea, due to a failure of communication between shifts.	0	0	Yes	\$99,085 (Legal Costs – July 23 <sup>rd</sup> 1985 GBP to USD Exchange Rate: 70,000 x 1.4155) <b>Total: \$99,085</b>

Industry and government agencies continually advise to improve human procedures at industrial sites to help prevent catastrophic accidents.

## About Hexagon

Hexagon is a global leader in sensor, software and autonomous solutions. We are putting data to work to boost efficiency, productivity, and quality across industrial, manufacturing, infrastructure, safety, and mobility applications.

Hexagon's PPM division empowers its clients to transform unstructured information into a smart digital asset to visualize, build and manage structures and facilities of all complexities, ensuring safe and efficient operation throughout the entire lifecycle.

Hexagon (Nasdaq Stockholm: HEXA B) has approximately 20,000 employees in 50 countries and net sales of approximately 3.9bn EUR. Learn more at [hexagon.com](http://hexagon.com) and follow us @HexagonAB.