National Aeronautics and Space Administration

NASA SAFETY CENTER

SYSTEM FAILURE CASE STUDY

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From Rockets to Ruins

The PEPCON Ammonium Perchlorate Plant Explosion

May 4, 1988, Clark County, NV: What began as a normal repair procedure at the Pacific Engineering Production Company of Nevada (PEPCON), a chemical plant specializing in the manufacture of a major component in solid propellant, ended in the worst way imaginable. While many workers were leaving for lunch, sparks from a repair crew welding torch set ablaze fiberglass infrastructure. The flames, which grew out of control, soon engulfed PEPCON's massive stock of oxidizer, creating the largest domestic, non-nuclear explosion in recorded history. The explosion affected structures in a 10-mile radius, accrued damages estimated at $100 million, injured approximately 372 people, and ended the lives of 2 plant employees.

PROXIMATE CAUSE

- Sparks from a welding torch used during repairs ignited fiberglass material; the fire grew at an accelerated rate because of accumulated ammonium perchlorate residue at the facility

UNDERLYING ISSUES

- Stockpile of AP
- Improper Hazardous Material Storage Practices
- Complacency

AFTERMATH

- Multiple lessons learned, including the public need for accurate and timely information during emergency conditions, consideration of human nature during evacuation planning, and of safely evacuating handicapped individuals from disaster areas
- Nevada Environmental Protection Division attempted measuring the amount and effects of AP spread across the landscape from the explosion, possible contamination of surrounding landscape

Background

Ammonium Perchlorate

For decades, the powerful oxidizer that is ammonium perchlorate (AP), has been mixed with finely ground aluminum and other combustible materials to create solid propellants for launch vehicles and military weapons. AP production involves several hazardous compounds and many were present in bulk at the facility. Until the PEPCON event, AP had been tested in small scale detonation scenarios and was classified as a class-4 oxidizer. Although classified as less hazardous than mixed fuel, AP greatly accelerates the explosive properties of combustible material.

The PEPCON Facility

At the time of the explosion, PEPCON was one of two major producers of AP worldwide. The other producer, Kerr-McGee, was located less than 2 miles away—well within the blast effect area of the PEPCON explosion.

PEPCON operated in Clark County, NV, located approximately 10 miles southeast of downtown Las Vegas, NV, near the City of Henderson. Henderson was a growing suburb with a 1988 population of approximately 50,000 and had been a center of production for the commercial and defense industry since World War II.

In 1988, all NASA launch activities had been indefinitely halted by the Challenger

Figure 1. The PEPCON facility before the blasts. Source: Lawrence Livermore National Laboratory.

disaster on January 28, 1986 and subsequent investigative activities of the Rogers Commission. The stand down froze PEPCON's AP shipping, yet had no effect on PEPCON's AP contract orders with Space Shuttle Solid Rocket Booster (SRB) manufacturer Morton Thiokol. Over the next 15 months following the Challenger disaster, PEPCON had accumulated a stockpile of over 4,000 tons of the oxidizer.

What Happened

On May 4, 1988, PEPCON employees were repairing the plant's wind-damaged steel and fiberglass drying structure when, at 11:30 a.m. Pacific Daylight Time (PDT), sparks from a welding torch ignited some of the fiberglass building material. The workers attempted to extinguish the fire with a hose line, but then charged a second hose line, which reduced the water pressure, and allowed the fire to grow. Exacerbating the situation was the profusion of AP residue on many of the drying structure's surfaces. The fire spread quickly to the 55-gallon AP storage drums stacked next to the drying structure. Within 10 to 20 minutes (estimated by PEPCON employees) from the time of the spark, the first AP explosion occurred.

No alarm or audible announcement system was installed at the facility, and no sprinkler system existed in the processing structures, except for the administration building. According to policy, personnel were advised to evacuate the premises if they observed a fire beyond beginning stages; however, there was no formal evacuation plan.

Of the 77 PEPCON employees, 75 escaped, running or driving away from the facility through the desert. Two were killed; one, confined to a wheelchair, was unable to escape in time, the other—who was also handicapped—stayed behind to alert emergency dispatchers of the situation. Employees at the neighboring Kidd Marshmallow plant also evacuated and contacted authorities. Fire response teams dispatched to the area immediately following the calls, which began at 11:51 a.m. PDT. The closest Clark County units were a little over 5 miles away and saw smoke from their station. The Fire Chief of the City of Henderson, 1.5 miles away, saw smoke and also ordered his units to dispatch to the PEPCON plant.

At 11:53 a.m. PDT, multiple 55-gallon drums exploded into a giant fireball—the first of two major blasts—approximately 100 feet in diameter. The shockwave shattered vehicle windows of the fire response units, halting their approach. PEPCON employees escaping in vehicles met the responders and warned of potential, larger explosions, sending the responders in the same direction as the escaping workers. Four minutes later, at 11:57 a.m. PDT, the fire reached the storage area of the facility that held large, aluminum 5,000-pound shipping containers loaded with AP, resulting in the largest explosion.

Witnesses reported a shockwave visibly travelling across the ground toward them. Many were temporarily blinded by the immediate flash and others lacerated by flying glass. Henderson responders were effectively incapacitated. Of the 4,000 tons of AP stored at the plant, it is estimated that approximately 1,500 tons were consumed in the subsequent explosion.

Figure 2. Each Space Shuttle SRB is loaded with approximately 550 tons of propellant. AP makes up 69.6% of the fuel (382.8 tons by weight) commonly referred to as Ammonium Perchlorate Composite Propellant (APCP). The remaining mixture comprises aluminum fuel (16%), iron oxide catalyst (0.4%), a polymer binder and secondary fuel (12.04%), and an epoxy curing agent (1.96%). NASA.

Figure 3. It is estimated that the second major explosion consumed 1,500 tons of AP—almost four times the ammount of AP consumed by one Space Shuttle Solid Rocket Booster. Source: Public Domain

Little fuel remained after this second major explosion and flames diminished rapidly. At 12:59 p.m. PDT, the damaged facility gas line that continued to feed the remaining flames was closed off. Clark County responders staged 1.5 miles away and provided assistance to the injured Henderson responders. Several additional area fire departments responded with mutual aid, but no attempt was made to approach or fight the fires, which were beyond the departments' suppression capability.

The PEPCON facility and neighboring Kidd Marshmallow plant were completely obliterated. The shockwaves had damaged buildings in Henderson; shattering windows, cracking walls, and breaking doors. The affected area spanned a 10-mile radius from the PEPCON facility.

Smoke rose several thousand feet on the thermal column created by the fire and travelled downwind and eastward over residential and commercial zones of Henderson. The smoke was seen from 100 miles away. The two major blasts measured 3.0 and 3.5, respectively, on the Richter scale at observatories in California and Colorado. Investigators surveying the damage in the surrounding communities estimated the blast as similar to a 1-kiloton airblast nuclear detonation.

Proximate Cause

Sparks from a welding torch used during repairs ignited fiberglass material. The fire grew at an accelerated rate because of the general profusion of AP residue at the facility. A surplus of AP exploded in the fire.

Underlying Issues

Stockpile

Although all shuttle launches were postponed in wake of the Challenger disaster and the Rogers Commission, the SRB manufacturer did not alter or halt contracted AP production. PEPCON continued to produce AP at a pre-Challenger rate and stored it wherever space permitted.

Figure 3. A truck displaying the effects of the shockwave from the second explosion. Source: United States Fire Administration.

Figure 5. Remnants of the PEPCON facility. Source: Lawrence Livermore National Laboratory.

PEPCON Storage Practices

Containment choices at PEPCON included 5,000-pound capacity aluminum bins, 250-pound capacity polyethylene lined steel drums, 2,400-pound capacity fiber reinforced polypropylene bags, and 550-pound capacity high-density polyethylene drums. The 550-pound capacity drums, of which there were over 10,000, were stored at various locations around the facility, often wherever extra space dictated as the surplus accumulated. The drums were chosen for convenience and corrosion control.

Although AP is an oxidizer and thought to be relatively safe to handle before the addition of combustible substances, all storage containers were composed of or contained oxidizable material. Thermodynamic evaluations of the energies and entropies of AP alone and AP in conjunction with polyethylene in particular, reveal staggering differences relative to 50 percent and 150 percent the explosive strength of the same amount of TNT, respectively. Although the combination of a polyethylene drum containing AP is oxidizer-rich, investigators suggested that the inclusion of the polyethylene drums had amplified the magnitude of the PEPCON blasts.

Complacency

Beyond the surplus of oxidizer, AP residue was present throughout the facility from years of production. Dust from the batch drying process deposited on the walls and layered on flat surfaces. Housekeeping was only performed thoroughly when inspections were scheduled and announced.

Previous fire incidents in the batch dryer building occurred because of belt and brake friction from the machinery; electrical sparks; welding sparks; and motor overheating. Although these fires were extinguished with water from hoses, PEPCON had never installed a fire alarm or sprinkler system to mitigate damages from fires.

Aftermath

In their report, the U.S. Fire Administration, the Federal Emergency Management Agency (FEMA), and the National Fire Data Center recommended several lessons learned, ranging from land development decisions to the need for emergency triage center procedures for overwhelmed hospitals. There was a particular focus on lessons concerning human behavior. The public need for accurate and timely information during emergency conditions, consideration of human nature during evacuation planning, and of safely evacuating handicapped individuals from disaster areas.

The U.S. Fire Administration, FEMA, and the Department of Energy (DOE) also noted that several vital safety procedures and systems were lacking at PEPCON, citing in particular, the need for better housekeeping and fire watch practices and the need to eliminate fuel sources and combustible building products. Investigators also noted the lack of ventilation systems, sprinkler and deluge systems, alarms, fire sensing systems, and evacuation procedures.

The Nevada Environmental Protection Division has attempted to measure the amount and effects of AP spread across the landscape from the explosion.

PEPCON never rebuilt the Henderson site, but changed its name to Western Electrochemical Co. and built a new AP plant in Cedar City, UT which is still in operation. Since the 1988 disaster, one deadly explosion (involving one victim killed and three other wounded) has occurred involving a spark that caused a flash fire and explosions. Official investigators blamed the blasts on welders, cramped storage, poor housekeeping, and windy weather.

Relevance to NASA

Although NASA continues to reassess and replace aging containment systems and methods, the mere storage of hazardous material presents an everlasting requirement of caution.

The May 4, 1988 PEPCON explosion still evokes astonished hindsight. With such vast explosive potential, how could the hazards of welding on such a structure constructed in part with flammable material not have been better assessed? It would be logical to minimize the relevance of this map of causes to an individual's work or project, especially if the individual's work does not involve hazardous material. But the dangers of potentially hazardous material (e.g., ammonium perchlorate, solid propellant, liquid propellant, hydrogen, hypergols) force us to realize things that have never happened before happen all the time.

Planning for failure, like designing for success, sometimes depends upon key assumptions to scope and scale the effort to the resources available. This scoping and scaling can lead to planning for the scenarios considered most likely, instead of worst credible. Coping with the worst credible outcome can easily exceed available resources; NASA should not only plan to prevent the (disastrous) outcome, but also how best to recover lost critical functionality by accessing other resources.

Although the PEPCON disaster could have been even more catastrophic in terms of loss of life, the effect of disasters and emergencies have a resounding impact on the public in close proximity and also those far away.

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Responsible NASA Official: Steve Lilley steve.k.lilley@nasa.gov

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