

Incident

Texas City 1947 — America's worst industrial accident

Phillip Carson and Tony Fishwick

Summary

A ship containing fertilizer detonated in a port 75 years ago this month. The explosion initiated a chain of events resulting in America's worst industrial disaster in terms of loss of life due to a single event. The accident and its causes are reviewed. Parallels are drawn to the 2020 explosion in Beirut.

Keywords: Ammonium nitrate

Introduction

In August 2020 ca 2750 t of ammonium nitrate exploded in the port of Beirut resulting in 207 fatalities, 7500 injured and \$15 billion collateral damage. Dangerous properties of this compound, the cause of the accident together with hazard prevention and risk control measures were discussed by Tariq¹ with a responder's perspective provided in a companion paper by Evans.² Numerous previous explosions involving this compound^{1,3,4d} have occurred globally as exemplified by the following brief description of a similarly catastrophic disaster 75 years ago. This in itself provided ample warnings for Beirut and served as a stark illustration of how quickly incidents, and the lessons that can be learned from them to prevent repetitions, are forgotten.

Background⁴

The strategic potential of a deep-water port at Texas City leading to the Gulf of Mexico was recognised at the end of the

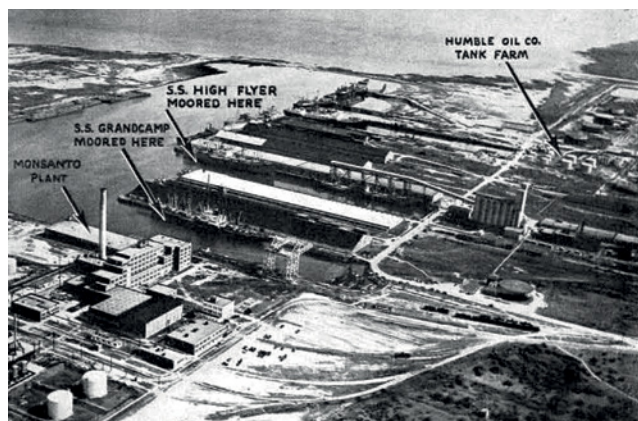


Figure 1 – Depicting the Port and juxtaposition of ships and Monsanto Chemical Co (Reproduced from *Fire Engineering*, May 1947)

19th Century. Work to develop the site commenced in 1893 with extensive industrial expansion around the port to support efforts during and immediately after World War II, including production facilities for petrochemicals, tin smelting, and oil refining.

In April 1947 the *SS Grandcamp* was moored at Pier O, Texas City port (see Figure 1). The vessel, originally the *SS Benjamin R. Curtis*, was used by America to ship ammonium nitrate for munitions during World War II. At the end of the conflict the ship was assigned to the French as a goodwill gesture, renamed, and used for hauling the chemical to Europe for use as fertilizer.

Ammonium nitrate (AN) fertilizer, mixed with rosin/paraffin wax/clay to prevent caking, and packed into 100lb paper bags was sourced elsewhere and shipped by rail to Texas City. Allegedly, the weather was warm enroute. The loading of fertilizer sacks commenced on 11 April, but the operation was hampered by heavy rain. By the morning of 16 April, the *SS Grandcamp's* mixed cargo comprised a considerable number of bales of sisal twine, cotton, machinery, tobacco, peanuts and other items. Some were carried on deck but most below deck including 2,300 t of fertilizer stowed in holds 2 and 4, with 16 wooden boxes of small-arms ammunition in hold 5, and fuel-oil housed in tanks between holds 3 and 4.

The *SS High Flyer*, also moored at Pier O, carried a cargo ca 900 t of ammonium nitrate in her hold 3 together with 2000 t of sulphur in holds 2 and 4. She was moved to Pier A to take on additional cargo and was also destined for France. Across the main slip from *SS High Flyer* the *SS Wilson B. Keene* was being loaded with flour.

The accident⁴

While preparing to finish loading, dock workers noted smoke billowing from the cargo hold of *SS Grandcamp* around 8am. Attempts to put out the fire with a gallon jug of water and two fire extinguishers proved ineffective. In order to keep the cargo intact, the captain decided not to use water to extinguish the fire but instead to batten down the hatches and snuff out the flames with steam. This was a common fire-fighting practice aboard ships at the time to minimise damage to cargo and prevent the hold from flooding with water. Workers began moving crates of ammunition from hold 5 which was separated from the fire by a 0.3 inch (8mm) steel barrier. After only three crates had been removed, the men were instructed to leave the ship.

Crowds gathered to watch the operation and at 8.30 am the temperature and pressure within the hold had risen enough

knowledge and
competence

engineering
and design

systems and
procedures

assurance



Figure 2 – Monsanto Chemical Company ablaze at Texas City

to blow off the hatches and release orange smoke plumes (probably nitrogen dioxide). Just after 9 am the ship detonated with a massive explosion that was heard 150 miles (240 km) away with tremors felt 250 miles (400 km) away. The blast initiated a catalogue of domino effects.

The ship's 40-member crew, hundreds of onlookers, and 28 firefighters (almost the town's entire fire-brigade) were killed instantly. The blast ejected much of the ship's 6000 t steel into the air, and released *SS High Flyer* from its moorings which then drifted alongside the *SS Wilson B. Keene*. Nearly 1,000 buildings were levelled, including most of the dock area, adjacent warehouses (some containing fertilizer), the nearby Monsanto chemical plant killing 145 of its 450 workers (see Figures 2 and 3), local businesses and residential properties rendering up to 2,000 people homeless. A mushroom cloud rose 2,000 feet (600 metres) into the air reportedly destroying two small planes passing above. Molten shrapnel landed in industrial areas, setting off fires in oil refineries, chemical tanks and ships along the waterfront, including the *SS High Flyer*. The blast shattered windows within a 10-mile (16 km) radius. *SS Grandcamp's* 2-ton anchor was hurled 1.62 miles (2.5 km) and was found in a 10-foot (3 m) deep crater near the Texas City railway terminal. The ship's other 5-ton anchor was found 1/2 mile (800 m) away. Over 1000 vehicles were damaged (including the four fire-fighting trucks and their associated equipment), and 362 freight cars destroyed. The 150ft (45 m) Longhorn oil barge anchored at the port was lifted into the air by the blast and landed 100 ft (30 m) away on the shore.

Attempts failed both to extinguish the fire aboard the *SS High Flyer* with water and to tow her away from the vicinity to minimise the consequences of the now-inevitable second explosion. Thick oily smoke and sulphurous fumes forced the crew to abandon ship and at 1.10 am on 17 April a second,

allegedly more-catastrophic explosion occurred destroying *SS High Flyer* and obliterating the *SS Wilson B. Keene* nearby. The pier and grain elevators were demolished with more molten debris sent flying to start further fires and thereby adding to the death toll and destruction from the previous day's tragedy. One of *SS High Flyer's* propellers was subsequently discovered approximately one mile inland. Although some of the fires were extinguished when a 15-foot (4.5 m) mini tidal wave, created by the first blast, flooded parts of the harbour area, many fires in the area continued to burn for over a week which was exacerbated by the destruction of the town's fire-fighting capabilities.

Post the accident⁴

No central disaster plan and organisation had been prepared by the city, but most of the local chemical and oil plants had emergency plans that were quickly put in to action, albeit somewhat hampered by the lack of water and power. Hundreds of local volunteers supported by Red Cross personnel and responders from neighbouring cities assisted with rescue and emergency aid. Temporary hospitals, morgues, embalming rooms and shelters were established.

Estimates were that nearly 600 people lost their lives (63 never identified) and almost 4000 were injured during the two days of America's worst industrial accident; the exact number of fatalities is unknown because of the condition of many of the bodies and an unknown number of visiting seamen and itinerant dock workers. In addition, all records of personnel and payrolls of the Monsanto Company were destroyed. The devastation caused property damage estimated at US \$1.2 billion (at 2021 rates) with \$4.5 billion worth of oil products lost.

Public commemoration of the event began in June of 1947 when a park containing artefacts and plaques was established



Figure 3 – Rescue workers search through debris near the Monsanto Building after the Texas City Disaster of 1947 (Courtesy of Moore Memorial Public Library, the John P. Blizetec Collection)

in Texas City in memory of those lost during the tragedy. At the centre of the park is the 2-ton anchor from the *Grandcamp*. A sculptured marbled angel is dedicated to the firefighters who were killed, and a small cemetery contains the remains of the 63 unidentified victims. A new section was added to the park in 1991.

Some temporary housing was built and donated to the city, and other housing, docks, warehouses, and chemical plants were rebuilt by 1950. 1,394 survival victims filed the very first class-action lawsuit seeking compensation, but it wasn't until 1957 that Congress completed its compensation of \$17 million to the 1,394 claimants

The disaster catalysed changes in chemical manufacturing and new regulations for the bagging, handling, and shipping of chemicals.

Discussion⁴

Technical causes

The technical cause of the fire and explosion aboard *SS Grandcamp* is unknown with speculation that the fire could have been started by a discarded cigarette; two days before the explosion a fire amongst sacks of AN in another of *Grandcamp's* holds was claimed to have been started by a burning cigarette. The influence of heat on AN is itself able to create danger under certain conditions (see Appendix 1). By 1947 it was known that AN could ignite or explode under certain conditions but no one handling it knew the dangerous circumstances. It had also been established that AN coated with organic matter was more prone to detonation than pure AN, especially when hot. The fact that the AN, packaged in heavy paper sacks, may have been stored at higher than normal temperatures before being loaded onto the ship could have been a contributing factor. Dock workers reported the bags were warm to the touch before they were loaded. The higher temperature may have increased the rate of thermal decomposition of the bulk fertilizer in the confined space as may the steam used in the futile attempt to douse the fire in the sealed hold. Even prior to this disaster it had been established that the most effective way to extinguish fires involving AN

was application of copious volumes of water to reduce the temperature. Furthermore, since AN is an oxidizer with its own oxygen supply, it is able to support combustion in an otherwise 'oxygen-deficient' atmosphere. Steam may have converted a significant amount of the ammonium nitrate to nitrous oxide, increasing the heat and pressure in the confines of the hold. The paper sack containers and the rosin/wax in the fertilizer also provided a potential fuel in intimate contact with oxidizer. Impurities (e.g. in the clay additive or S dust) are known to reduce combustion temperature. It was claimed that the likely trigger for the explosion was fuel oil leaking as a consequence of fire on to burning AN. In 1944 a similar explosion had occurred at an ordnance plant in Tennessee when lubricating grease and oil dripped on to molten AN.^{4a}

The use of S in high explosives was well established but it is unlikely the reaction between AN and S would have been fully appreciated in 1947 and was only published some 20 years later⁵. Nevertheless, the presence of elemental sulphur on *SS High Flyer* may have exacerbated her demise whilst the flour on *SS Wilson B. Keene* theoretically could have formed an explosive dust cloud to add to her woes. Whatever the initial source of ignition the outcome was two spectacular deadly explosions and many fires that should not have occurred.

Human factors

As is often the case, public blame for the disaster was targeted at individuals including *Grandcamp's* crew for possibly discarding a lit cigarette, and the ship's mate for the manner in which he attempted to deal with the fire. Clearly, had they been aware of the dangers it is highly unlikely these actions would have been undertaken. There was failure to provide hazard information/training to those handling and managing the fertilizer. Labelling of the paper bags (see Figure 4) provided a false security since there were no instructions concerning the handling of the material nor was it labelled as being hazardous with no coloured lettering (often Yellow) to attract attention to a hazardous nature. Indeed, the vice president of the Texas City Railway Company stated that he considered AN to be safe and similar to handling cement, despite the US Dept of Agriculture in 1943 recognising AN to be a high explosive. Apparently, the Port of Houston prohibited loading of AN fertilizer because of risks.^{4a}

Questions then focus on government for lax legislation. Accountability for safety at Texas City was fragmented. In the absence of a port authority, responsibility for health

FERTILIZER

(Ammonium Nitrate)

32.5% Nitrogen

100 lbs. Net

101.5 lbs. Gross

1.6 cu. ft

Made in U. S. A.

Figure 4 – Labels on bags of fertilizer with the letters shown in relative sizes as they appeared on the bag⁶

and safety was fragmented and left by default to Terminal Railway but with no jurisdiction aboard ships which was the responsibility of the shipping agents and Coast Guard. This led to inadequate management and supervision. Hot bags of AN were often loaded on board in a brittle and torn state leaking contents in ships' holds and onto other incompatible cargo and not cleaned up as required. "No smoking" signs were displayed at the docks and on ships but despite being a known common practice the rules were never enforced.

When *High Flyer* caught fire valuable time was lost in dealing with the incident because relevant people were not informed and did not know that she carried AN.

There was little regard for planning to prevent hazardous industries co-existing in close proximity to each other and to residential dwellings. Also, there were no plans for dealing with the aftermath of major disasters. A formal investigation report⁶ drew attention to the need to prohibit smoking and use of open lights on piers or on docks at any time regardless of cargo being handled since they pose a common source of ignition. It also emphasised that any port facility and city where large industrial operations are present should possess a complete disaster plan which anticipates the worst possible scenario. It should involve all relief agencies e.g. police, fire, medical departments, civil officials and where applicable military authorities.

Furthermore, the Texas City's poor standard of record retention has prevented others from maximising their learning the lessons.

Conclusions

Texas City

At the time of the accident the science, safety standards, and legislation relating to ammonium nitrate were less well-developed than nowadays. Nevertheless, some of these postulated causes could reasonably have been foreseen and measures put in place to avoid or mitigate them. The most significant root causes include:

- An inadequate regulatory regime for shipping, handling and transportation of AN fertilizer.
- Inadequate understanding of AN hazards and provision of information, guidance and training.
- Uncoordinated responsibility for, and complacency towards, health and safety landside and waterside and absence of supervisory enforcement of day-to-day hazardous activities.
- Inability to learn lessons from previous accidents. Arguably, government authorities should have been more aware of the risks with ammonium nitrate after the Oppau explosion⁷ – indeed there had been eleven major fires/explosions involving AN fertilizer prior to Texas City. In July 1947 the *Ocean Liberty* carried 3,300 tons of AN fertilizer from Baltimore to France. Whilst unloading she caught fire. Attempts to smother the fire by closing portholes were unsuccessful. Within a short while she was destroyed in an explosion involving petroleum barrels and AN in adjoining holds and killing 20, injuring approximately 500 and causing \$5 million waterfront damage. This failure to learn from past mistakes extends

from operator to regulator. In West, Texas on April 2013 a fire started at a fertilizer company storing AN. The nitrate exploded, levelling about 80 houses and trapping 133 residents of a nursing home. Fifteen people were killed and about 260 injured. It was reported that the facility exceeded the storage limit without approval from the Department of Homeland Security. The Chemical Safety Board report also noted that OSHA and the Environment Protection Agency had both failed to use their regulatory powers to address the hazardous nature of AN and to make recommendations for safety improvement.

- Lack of a central disaster plan with associated organisation and training.
- A failure to consider elements listed in Appendix 2 for the safe storage of AN fertilizer.

Other measures, incorporating 21st century risk assessment, safety management systems and modern-day tools such as HAZOP, could not have been employed.

Parallels with Beirut explosion

- The accidents at both Texas City and Beirut involved AN fertilizer stored at ports under cramped conditions and exposed to hot humid environments with incompatible materials nearby and with no controls over ignition sources.
- Whilst the risks with AN may not have been fully appreciated in 1947 the dangers of this compound and the safety requirements were clearly well known by 2020 and highlighted by the fact that no fewer than 24 accidents involving AN occurred across eleven different countries and resulted in some 540 fatalities before the Beirut explosion including Texas City itself, which was well publicised in the literature and even featured in a TV film⁹. Again, this illustrates a failure to learn from previous catastrophes. Barriers to learning from history have been discussed elsewhere¹⁰.
- Allegedly Beirut port officials had warned the government of the dangers but requests for removal of the fertilizer were ignored for unknown reasons¹.

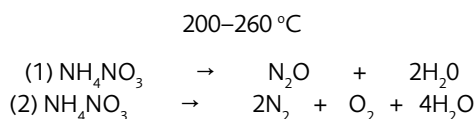
As with Texas City this illustrates a government's dereliction of duty regarding public safety.

- Both accidents suffered from inadequate regulatory and inspection system with no government oversight.
- Responders arrive on scene with no appreciation of the risks involved.
- Both incidents overwhelmed emergency services.

Appendix 1 — Thermal degradation of ammonium nitrate

'Pure' ammonium nitrate is considered a stable salt that can be stored safely under normal conditions. However, its thermal breakdown is complex and influenced by a variety of factors such as particle size, temperature, pressure, humidity, confinement, the presence of reducing agents including inorganics such as sulphur and certain metals, or organics such as charcoal (from paper), diesel oil, grease, etc. Low levels (e.g. 0.1%) of some chlorides cause the nitrate to decompose explosively below 175°C.

In theory decomposition of *pure* material at elevated temperatures, and breakdown on extreme shock, occurs according to at least one of the following two routes.



The first reaction may be performed safely under controlled conditions when the salt is heated to about 210°C and it forms the basis for the manufacture of nitrous oxide. The second reaction takes place with great rapidity and forms large volumes of gases when the compound is subjected to extreme heating under confinement, or when initiated by a priming explosive charge.

Although the above two reactions characterise the extremes of controlled decomposition and complete detonation, in reality decomposition may take place according to both equations in varying ratios. Higher oxides of nitrogen may also be formed.¹¹

The resulting heat and pressure from the decomposition may build up if the reaction takes place in a confined space (e.g. tanks, shipping containers).¹² As the temperature rises, the rate of decomposition increases. In a confined space, the pressure can reach dangerous levels and cause an explosion that will include the detonation of the ammonium nitrate. When dealing with a large quantity of ammonium nitrate, localized areas of high temperature may be sufficiently confined by the mass of material to initiate an explosion. The explosion of a small quantity of ammonium nitrate in a confined space may act as a booster charge and initiate the explosion of larger quantities. The evolution of either nitrous oxide or oxygen enables materials to burn in an atmosphere otherwise starved of air (i.e. external source of oxygen).

Appendix 2 ^{after 8}: Factors to consider for safe storage of AN fertilizer

Factors include the following:

- design (e.g. climatic conditions, avoidance of combination of heat and confinement, etc.)
- materials of construction
- absence of ignition sources
- fire prevention and control
- specification and volume of the fertilizer stored
- prevention of contamination by extraneous matter
- nearby presence of incompatible materials
- housekeeping
- security
- planning

- training and provision of hazard information
- regulation and monitoring
- thorough emergency procedures to mitigate the consequences of a loss of control
- the dangers of the public treating disasters as a "free firework show" with the 21st Century phenomenon of spectators filming emergencies on mobile phones. These impede escape routes for those affected, hampering the efforts of emergency response teams, and potentially increasing the number of casualties.

References

1. Tariq, Z., *Loss Prevention Bulletin*, 2022(284), 2
2. Evans, D., *Loss Prevention Bulletin*, 2022(284), 7
3. a. Gyenes, Z., *Loss Prevention Bulletin*, 2016(251), 32 b. Gyenes, Z., and Wood, M., *Loss Prevention Bulletin*, 2015(242), 15 c. Dechy, N., Gyenes, Z., and Merad, M. *Loss Prevention Bulletin*, 2019(269), 25
4. a. Stephens, H.W. *The Texas City Disaster*, 1947. University of Texas Press, 1997 b. 1947 Texas City Disaster: The Deadliest Industrial Accident in US History (freerangeamerican.us) c. Texas City explosion of 1947 | industrial disaster, Texas City, Texas, United States [1947] | Britannica d. Texas City disaster - Wikipedia e. 1947 Texas City Disaster | Texas City, TX (texascitytx.gov) f. TSHA | Texas City Disaster (tshaonline.org) g. Texas City Explosion (1947) | Uvadisasters Wiki | Fandom h. Beirut Explosion Stirs Memories of 1947 Texas City Disaster (spectrumlocalnews.com) i. Texas City disaster - Alchetron, The Free Social Encyclopedia
5. a. Mason, C.M. et al, *J. Agri. Food Chem.*, 1967, 15, 954 b. Prugh, R.W., *Chem. Eng. Progr.*, 1967, 63(11), 53
6. Texas City Disaster Report (local1259iaff.org)
7. Oppau explosion - Wikipedia
8. a. Shah, K.D., *Loss Prevention Bulletin*, 2018(268), 2 b. HSE INDG230 Storing and handling ammonium nitrate - <http://www.hse.gov.uk/explosives/ammonium>
9. Explosions! Texas City (TV Movie 1999) - IMDb
10. Bunn, J. and Carson, P.A., *Loss Prevention Bulletin*, 2021(282), 7 and 2022(283), 21
11. Carson, P.A., *Loss Prevention Bulletin*, 2019(265), 17; *ibid* 2020(273)
12. a. Du Teaux, S.B., in *Encyclopaedia of Toxicology* (Third Edition), Elsevier 2014 b. van den Hengel, E.I.V., et al, *Loss Prevention Bulletin*, 2008(202), 19