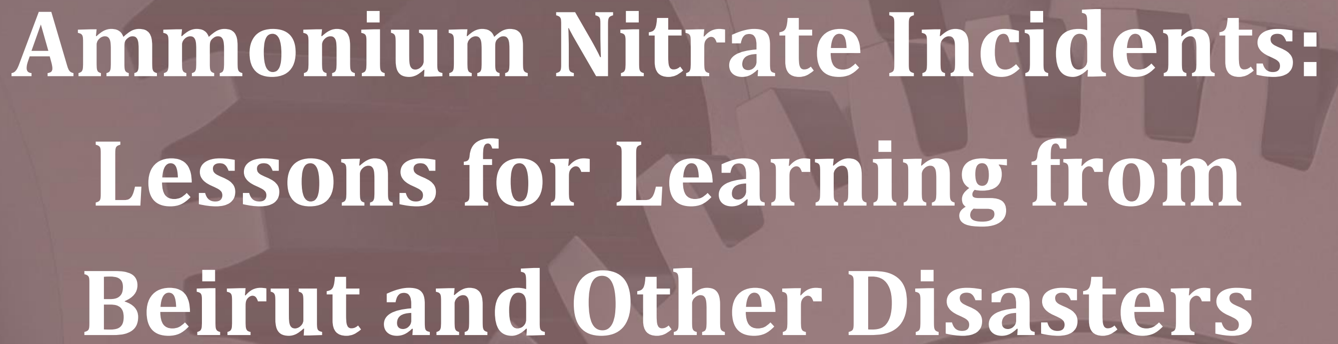

Ammonium Nitrate Incidents: Lessons for Learning from Beirut and Other Disasters

An Online Continuing Education Course for Engineers

Course Number: ED-3002

Credit: 3 Hours / 3 PDH / 3 CPD

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Ammonium Nitrate Incidents: Lessons for Learning from Beirut and Other Disasters

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Prologue

The first concern related to any incident or accident should be the care for people. People will be affected by the consequences of any adverse event. Beginning with the first deadly Ammonium Nitrate Explosion (ANE) in Faversham, Kent, UK (April 2, 1916), known as "The Great Explosion" at an Uplees factory, which killed 115 people on to Beirut, Lebanon (August 4, 2020), and where the death toll stood at 200+ at the time that this course was published, we continue to suffer adverse events.

In America, April 16, 1947, SS Grandcamp cargo ship exploded while still docked in Texas City. This remains the deadliest ANE incident today. For the fortunate ones that survive these incidents, their lives are adversely impacted, and they may very well continue to have lasting impacts for generations. Some people affected may never recover both physically and psychologically from the losses suffered.

A serious incident impacts every aspect of a community, from dealing with tragic and untimely deaths, loss of livelihood, and loss of housing and business. No one outside those impacted or involved can ever understand what effects an event of this magnitude has on a community. All we can do as outsiders is pray, support, grieve, and promise to learn from these events. Our hearts and prayers are with all those affected by these incidents.

Why Do We Study Past Incidents?

The costliest learning events derive from our past failures. This is not the ideal place to learn. However, we cannot ignore the potential learning value from past incidents. We study past incidents for the purposes of information sharing so that we do not repeat the same mistakes. However, the contextual structure of any incident investigation is important so that you can determine what the learning value is and any limitations.

In just over a century, there have been over thirty well known accidental detonations of Ammonium Nitrate around the globe. These have caused nearly 2,200 fatalities, tens-of-thousands of injuries, and billions of dollars in property damage and lost opportunity.

If you are like the author, you may ask yourself, "Why do we keep having these incidents?" In this course, we will review several major case studies/incidents and look for common themes. The course "***Introduction to Data Trending***" demonstrates how to take multiple data sets, such as incident data, and pull out common trends. "***Incident Investigation Principles & Techniques***

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101 and Advanced Incident Investigation Principles and Techniques 201" both offer tools on conducting incident investigations. Understanding these processes aids the student in objectively reviewing not only the **What** and **Why** of past incidents but **How** causes are determined. Further, **Where** the focus of any improvements should center.

The study of past incidents for the Professional Engineer is not to entertain, but to gain unknown knowledge and apply it in our daily practices. Lessons for learning are an essential part of any Professional Engineering education. The pain of learning these lessons, again and again, is what we are trying to avoid. However, many times we fail to learn, or because situations and conditions are changed, we do not properly apply the lessons of the past. Let's proceed to discover what we can learn together from these ANE events.

Case Studies

Over the past century, there have been seven deadly ANEs in various locations around the globe. All seven have an excess of 100 fatalities, with all but one having over 150 untimely deaths. Perhaps because of the length of time between these adverse events or the fact that they seem to cluster generationally, the lessons learned are not kept at the forefront. Additionally, public safety regulatory laws meant to protect the citizens become political weapons, deciding winners and losers for production, distribution, storage, and transport of highly hazardous chemicals (HHCs).

This course could delve deeper into **Who** is responsible, but for now, let's understand the **What** and **Why** of these adverse events. These seven events were chosen from the lot of thirty due to the consequences they levied against humanity.

In reviewing the list of the modern ANE incidents, we see that there were many ANE near misses. One-third of the ANE incidents on the list, if given a closer look and more scrutiny, may have aided in preventing the more deadly adverse events. Sadly, studying these incidents is not as exciting or morbidly curious enough for people to be interested in. Often times, industry and regulators congratulate one another, satisfying themselves that the safeguards and barriers they had in place worked. The deeper investigation into causation and determining **Why** they worked is almost never pursued. Curiously, this could be a factor in **Why** we continue to experience these catastrophic, life-altering events.

The case studies offered in this course are readily available on Wikipedia and many other internet data search engines. As we continue through, you are encouraged to perform your own research. Only facts and data the author feels appropriate for the course are included. As with any internet sources, some of the data and the interpretations of it can vary or be misrepresented. Care has been taken to be as accurate as possible, but the student is reminded this is not about a quality check on the internet sources as much as it is an opportunity to learn from the causes, consequences, and changes that were implemented after these adverse events.

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The Faversham, Kent, UK Incident

Incident Overview:

On Sunday, April 2, 1916, at 14:20, an explosion in a gunpowder factory in Uplees near Faversham, England, became the worst in the history for the British explosives industry. The explosion ripped through the gunpowder mill when a detonation due to a small fire of 25 tons of TNT (trinitrotoluene) set off the 700 tons of Ammonium Nitrate (AN) stored nearby. The initiating event was a fire amongst a few empty sacks that began what would be a catastrophic event resulting in the untimely deaths of 115 people.

The munitions plant was located in a remote area of North Kent, next to the Thames coastline. In the middle of an open marsh, residential density was a factor in the relative small number of fatalities. Densely populated areas and bystander congregation, such as the Texas City explosion in regard to the SS Grandcamp, play a significant role in the appraisement of how serious the incident was. This cheapens the lessons learned in the fact that no incident should be tolerable, regardless of the devastation to humanity, environment, and property.

A sidebar for a moment as to a near-miss vs. an incident. Oftentimes, the only thing separating the two is a single act, timing, or a held safeguard. In many cases, the potential learning from a successful catch is never investigated to understand the ***Why*** *of how it did not result in a catastrophic event.*

Incident investigations, a.k.a. root cause analyses (RCAs) are approached in two different manners. One to find causes, and the other to determine compliance. Companies generally look for both; however, RCAs conducted by regulatory agencies concentrate on compliance applicability.

Incident investigations look for what went wrong in route to preparing recommendations to improve. A flaw with common RCAs is that the mechanism to account for what went right is not always as obvious. An experienced investigator must leave the comfort zone of a narrow set of predetermined conditional causes to identify and document what went right. A scientific approach for determining a somewhat subjective set of catches may be cause for some scrutiny but could prove worthwhile. Knowing this bit of information could direct improvements in another direction, one of more value, and potentially prevent the catastrophic event.

The exact cause of this incident was never completely known, only surmised, as there were no witnesses to interview, and most of the evidence was destroyed. Perhaps hindsight and regret of housekeeping practices by management or owners led to this conclusion. The munitions plant had experienced several fires and small explosions leading up to this adverse event. It could be said that failure to learn from these near misses and small events, as described in the sidebar, could have potentially prevented this catastrophe.

To be transparent, nearby sheds contained another 3,000 tons of explosive materials. Fire and rescue teams worked desperately to contain the blaze and allow it to burn itself down until it could be subdued.

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Uplees Munitions Conclusion

Interpretation of evidence when there is so little available can only be an approximation. Housekeeping is the only obvious cause based on what is known about this incident. In fact, it is a conditional cause. Other conditions, such as handling and storage of the raw materials for production, could also have been a conditional cause.

A conditional cause is not a root cause. It is a cause of condition, meaning a circumstance of what may have been considered normal for this plant and its operations protocol. This is not to say that it is the safe or correct way in which to operate. Many RCAs utilize wrong conditions to search for causation and improvement. Neither here no there, remember that human acts are at the center of almost every cause, whether intentional, directed, or unintentional.

The general causes offered are here to add what little context about causes that can be found. Again, do not assume these offerings for this particular event as fact but context as to apparent conditional causes.

The Oppau, Germany BASF plant ANE Incident

Incident Overview:

On Wednesday, September 21, 1921, at 7:30, two explosions at the BASF plant in Oppau, Germany, destroyed the facility and leveled 700 homes in a nearby neighborhood. In total, 561 people were recorded as losing their lives due to this adverse event. A Popular Mechanics issue in 1921 provided the artwork in a rendering of the incident provided in this section.

The BASF plant produced ammonium sulfate (AS) prior to the start of World War I. As with many wars, Germany was unable to obtain the quantities of sulfur sufficient enough to maintain full production, so it converted its operations to produce ammonium nitrate in addition to ammonium sulfate.

AN, as compared to ammonium sulfate, is hygroscopic (see definitions), meaning it is soluble in water. So, the mixture of AS and AN compacted under its own weight in a storage silo approximately 65 feet in height. The plaster-like substance required factory workers to use pickaxes to remove it. The situation presented by this dilemma was problematic. Entry into the silo was not possible, and working from the bottom up meant a collapse could bury workers alive. Acceptable as a normal practice of the time, small charges of dynamite were used to break the mixture up so it could be easier managed.

Here, the phenomenon of normalization of deviance (NOD), an advanced causation finding, comes to bear. Success and confidence were gained at this facility, and others having performed

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this act before. As such, with every successful new act of detonating small charges in the silo were completed, the creep or slight modification in the process begins. Hypothetically speaking and purely to add context to this account, larger charges were probably made as human nature takes over common sense.

It was no secret that AN was explosive, having been used in theatre during World War I. Testing conducted at the time suggested that mixtures of ammonium sulfate and nitrate-containing less than 60% AN would not explode. Based on this premise backed by some flawed scientific research, the material handled at the BASF plant ran about 50/50 AN to AS. This loose science the AN-AS mixture to be stored in 50,000-tonne lots, more than ten times the amount involved in the Oppau catastrophe. It was estimated that nearly 20,000 charges were detonated, leading to the ANE on September 21. A lot of confidence or NOD can be gained, having flirted with disaster this many times with no adverse effects.

All persons directly involved with the Oppau catastrophe perished, so no one knows what really happened on that Wednesday morning in September. The science behind the 1919 tests with less than 60% AN being safe under small charge detonations was inaccurate. Mixtures containing 50% AN when detonated confined the explosion to a small volume around the charge. Increasing the proportion of AN to 55-60% greatly increases the explosive properties. This creates a mixture whose detonation is sufficiently powerful to initiate detonation in a surrounding mixture of a lower nitrate concentration, which would normally be considered minimally explosive. Changes in moisture content and density also affect the explosive properties of AN. It is also unknown if the mixture in the silo was uniform. There could have been an isolated pocket of AN instead of a 50/50 AN-AS mixture.

It was also known at the time from BASF records that in the months before the incident, the manufacturing process had changed. This change lowered the moisture content of the AN-AS mixture from 3-4% to 2%. This was done to lower the density. These factors would have increased the likelihood that the AN-AS mixture would explode. This would have been sufficient enough to detonate the surrounding AN-AS mixture. Additionally, a strong suspicion that an enriched AN pocket could have been present where one of the charges had been placed, which could have contributed as well.

As we discuss lessons for learning, it is an oddity to know that just a few months earlier, in Kriewald, Germany, 19 people were killed from an ANE. That explosion detonated 30 Tonnes of AN under similar conditions. It is not known why lessons from that incident were not taken into account. However, as we saw in the more recent Beirut explosion, we have not learned our lessons, or could it be that with each generation, we must relearn these lessons.

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Oppau BASF AN-AS Explosion Conclusion

There are several factors that contributed to this incident. T... ional causes were Knowledge gaps in their understandi... . Facilities siting issues with the plant being c... mber of fatalities. NOD in performing an unsafe ... , process or manufacturing change...

NOD played a huge rol... ployees were lulled into thinking that nothing ba... y believed was true. This was backed by hav... ng smalls charges in the past. Additionally, in... derstood, but up to that point, there had been... s course, it is clear to see how they slowly wen...

The author cautions you n... ns were run of some well-known incidents wit... s, the participants were placed in the same c... as closely as could be simulated and decision... a small few, the majority of the participants... the same outcome. Why share this? It is always easy to se... you have a globe in your hands, or you are circling it in a spacecraft. Now try seeing the world with a tiny eyepiece, a compass, and no maps to speak of.

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

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