Dust Explosion Involving Plastic Microspheres and Compressed Air

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Abstract
This paper is a review of a dust explosion and subsequent small fire(s) that involved the use of compressed air and plastic microspheres that are used to sensitize emulsions. Other than the event itself being detailed here, also explained are the conditions and actions leading up to the incident, the learnings from the event, and the action items taken to prevent such an event in the future.

Introduction
Nelson Brothers provides explosives products and services to open pit surface mines in the US as well as specialty chemicals to the explosive and industrial lubricant markets around the world. In the US explosives market, Nelson Brothers is a leading manufacturer of emulsion blasting agents and oxidizers. Nelson Brothers utilizes plastic microspheres in the manufacturing process to sensitize the emulsions from oxidizer to blasting agent. The plastic microspheres are received at the manufacturing facility in an unexpanded state. Nelson Brothers uses a specially designed heating process to expand the microspheres. The expanded plastic microspheres are then stored in a staging bin to be later used to sensitize oxidizers. The expanding equipment and process takes place in a separate and dedicated room, the Expander Room, adjacent to the emulsion production area of the facility. The Expander Room is 14' x 32' with an 18' high ceiling, and, is where the incident took place.

Main Body
On April 3, 2019, the Nelson Brothers St. Paul Emulsion Manufacturing Facility located in Quincy, KY, USA, experienced a dust explosion followed by subsequent small fires.

Actions and Conditions Prior to the Incident

1. The Expander Room Operator experienced a malfunction with the pump that pulled the unexpanded plastic microspheres from the poly-woven tote (i.e. raw material for this operation).
2. The Operator requested the assistance of Maintenance Personnel to repair the pump.
3. The Operator and Maintenance Personnel repaired the pump to a state where it began satisfactorily pulling unexpanded plastic microspheres from the tote and transferring to the Expander for expanding.
4. The Operator and Maintenance Personnel exited the room inadvertently allowed~~ing~~ the pump and the Expander to continue to run unattended.
5. The fill hopper that received the unexpanded plastic microspheres before entering the heat process was not equipped with any type of over flow switch that would automatically stop the pump.
6. Prior to this incident, any excess or "fly-away" unexpanded plastic microspheres that accumulated in the Expander Room was minimal and resulted in no build-up of dust.
7. Nelson Brothers personnel had routinely used both a vacuum and compressed air to clean any minimal build-up of unexpanded plastic microspheres in the Expander Room.
8. Nelson Brothers was not aware of any hazards associated with using compressed air for cleaning, partly because Nelson Brothers personnel, along with the manufacturer's personnel during periodic maintenance and repair visits, had used compressed air for cleaning.
9. Nelson Brothers had not trained the employees for any extraordinary spills of unexpanded microspheres.

The Event

Approximately 6 hours before the event, the pump that pulls the unexpanded plastic microspheres from the storage bag to the expander malfunctioned. The Operator shut down the process to investigate the pump malfunction. The Operator requested the assistance of the Maintenance Personnel to assist in repairing the pump. The pump was put back in operation and the process of pulling the unexpanded plastic microspheres from the storage bag to the expander resumed.

Commented [PI1]: Is it possible to include any photgraphs of the incident post event?

The Operator and Maintenance Personnel exited the Expander Room leaving the pump and the Expander unattended. One hour passed before the Operator re-entered the room. During the one hour the room was unattended, the pump continued to fill the hopper of the Expander. The hopper was not equipped with an automatic shut-off and therefore the unexpanded material over-flowed onto the top of the expander and throughout the room. There was approximately 6 inches of unexpanded material accumulated on top of the Expander, as much as one inch on the floor, and varying degrees of accumulation on other parts of the equipment and the room.

When the Operator re-entered the room, he immediately shut down the pump and the Expander. He then exited the room and notified other personnel and Management of the incident. The Operator prepared for cleaning the accumulated plastic microspheres the way he had always prepared to clean the room for routine maintenance of small and residual accumulations.

His first attempt at cleaning the room was to use an industrial vacuum. The Operator began the cleaning process with the vacuum and within the first minute of doing so determined the filter and vacuum could not handle the large quantities of microspheres. The next attempt was to use compressed air as was routine for cleaning small accumulations of dust. Keep in mind neither? this facility (nor any other Nelson Brothers Facility) had experienced cleaning up such a large accumulation of this product. The preparation for using compressed air included:

1. Connecting air hose to compressor at 140 psi
2. Connecting the 3 foot aluminum wand to end of air hose
3. Donning PPE – Hard Hat, Steel Toe Boots, Nuisance Dust Mask, Safety Glasses
4. Opening 8' x 10' roll-up door that exposed the room to the outside of the building

In addition, the Operator used an 8' step ladder to access the top of the Expander. The Operator began by making a general pass of the compressed air over parts of the equipment and floor. This use of compressed air was at a distance from large accumulated piles of dust and the wand was not placed directly into the piles. The Operator only made this motion with the compressed air wand for approximately 10-15 seconds. The Operator then ascended the ladder to better access the top of the Expander where there was a large pile of the unexpanded plastic microspheres.

When the Operator placed the end of the wand directly into the pile of microspheres, approximately 3 second afterwards, there was a dust explosion. The detonation of the material resulted in a fireball that was approximately 6 feet in diameter. Dust explosions, by nature, combust rapidly and therefore the fireball only lasts for a very short period. However, the fireball did ignite other accumulated unexpanded microspheres throughout the room.

The Operator descended the ladder at a rapid pace without falling, and as he exited the room and building, pulled the lever to activate the fire suppression system. The fire suppression system extinguished the remaining small fires within 8 seconds. The duration of fire event from dust explosion to fire being extinguished was 16 seconds.

Fire Suppression System

Because this was primarily a dust explosion and not a major fire, the damages to the equipment and the room was minimal. The sensors for the fire suppression system did not activate because the heat generated by the fireball and the small fires did not reach the required temperature, at the sensors, before the Operator manually activated the system.

Injuries

The Operator received first degree burns from the fireball to his neck (partial), face (partial), and left hand. Because the Operator was wearing a dust mask, hard hat, safety glasses and a long sleeve shirt, the

exposure to the fireball was minimal. He had no exposure to, and received no injuries from the subsequent small fires.

Technical Explanation for the Dust Explosion

There are five components of a dust explosion:
1. Fuel/Combustible Dust – Unexpanded Microspheres
2. Dispersion of Dust – Compressed air creating a dust cloud of Unexpanded Microspheres
3. Confinement of Dust – Confined to the room, could not freely escape
4. Oxidant – oxygen/air in the room
5. Ignition Source – static charge from compressed air causing friction with the Unexpanded Microspheres

There are two variables that must exist for a dust cloud to ignite.
1. There must be sufficient charge and,
2. There must be a certain density of the cloud.

The charge is defined as Minimum Ignition Energy (MIE) and is expressed in milli-joules (mJ).
The density of the cloud is defined as a Lower Explosion Limit (LEL) and an Upper Explosion Limit (UEL).

For this particular product (Unexpanded Microspheres), the required charge is 1.6 – 3.0 mJ.
And, the LEL is > 40 g/m3.

Dust explosions are classified based on their Kst value:

Dust Explosion Class	Kst	Characteristics
ST 0	0	No Explosion
ST 1	0-200	Weak Explosion
ST 2	200-300	Strong Explosion
ST 3	> 300	Very Strong Explosion

Examples of various combustibles and their Dust Explosion Class:

Sugar	ST 1 – Weak
Saw Dust	ST 2 – Strong
Aluminum Dust	ST 3 – Very Strong
Unexpanded Microspheres	ST 2 – Strong

Examples of various combustibles and the required MIE in mJ:

Powdered Sugar requires	30 mJ
Saw Dust requires	10 mJ
Unexpanded Microspheres require	1.6 - 3.0 mJ

Therefore, relative to other combustibles, when the density of the unexpanded microsphere dust cloud is between the LEL and the UEL, the product requires a small charge resulting in a strong explosion.

Root Cause

The dust explosion was caused from introducing highly compressed air into an accumulation of unexpanded plastic microspheres.

a. The initial introduction of the compressed air caused the plastic microspheres to become airborne and create a dust cloud with the density that satisfied the range between the LEL and the UEL.

b. Once the plastic microspheres were in a dust cloud that was in the explosion range, the compressed air caused friction with the individual plastic microspheres.
c. This friction caused static charge greater than the required 1.6-3.0 mJ resulting in the detonation of the dust cloud.

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HazOp Study

A Hazard and Operability Study was conducted to analyze the hazards that existed contributing to this incident as well as any other potential hazards that could lead to other incidents. The action items from the study were:

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1. Staffed Expander Room with a dedicated Operator that either monitors the equipment and operation from either inside the room or outside the room through video surveillance. Before the incident the operator had other duties that required he not be in the Expander Room at all times.
2. Equipped the Expander Hopper with a high-level shut-off.
3. Lowered the fire suppression system sensors closer to the potential heat sources.
4. Installed additional manual activation switches for the fire suppression system on the outside of the Expander Room.
5. Purchased Explosion-Proof HEPA Vacuum for cleaning.
6. Purchased non-sparking shovels for clean-up of large spills.
7. Developed SOPs for both Routine Cleanup and Non-routine Cleanup.
8. Removed all combustibles that are not essential to the operation.
9. Only allow a maximum of two totes of product in Expander Room. One for in-process and one staged for conditioning (temp and humidity).
10. Compressed air is not allowed to be used on this product.

Other Notes of Interest

1. The Expander Room was equipped with two video surveillance cameras recording both video and audio. And, an additional video surveillance camera located in the parking lot. All three cameras captured footage of the event. Without this evidence, and because the Operator was traumatized by the event, affecting his ability to remember details, it is highly unlikely that we would have been able to determine the root cause of the event. The video surveillance proved to be invaluable.
2. Knowledge of the hazards identified in the SDS of this product and the use of compressed air was clearly a major contributing factor to this event. Although the manufacturer of the product and the Expander equipment publishes training materials and other materials warning against the use of compressed air and promoting the use of a recommended HEPA Vacuum, Nelson Brothers was not aware of those specific materials. Nelson Brothers did possess the SDS that has these hazards identified.
3. Nelson Brothers and the Manufacturer of the product and equipment have worked closely together on this event to prevent this or anything similar from happening again at Nelson Brothers or any other Company that may use this product, process or equipment.
4. Although this event, a dust explosion and subsequent fire adjacent to the manufacturing and storage of hundreds of thousands of pounds of Blasting Agent, being of a very serious magnitude, Nelson Brothers views this as a very valuable learning experience to share with all and considers the lack of knowledge regarding the use of compressed air to be regrettable.

In Closing

All of industry has been aware of the hazards that exist with dust and dust explosions. However, from time to time, because of repeated practice with no event, we fall complacent in pushing the boundaries until there is an event. In Nelson Brothers case, we failed to make ourselves fully aware of this particular dust hazard, especially with a large accumulation of the product. And, although, warnings to not use compressed air were never communicated, the use of an approved vacuum was. Because of this incident, it

has reinforced us that anytime there is dust accumulation or the potential for dust accumulation, a hazard analysis must be done. Another important piece of information that came from the study of this incident was that of video surveillance. I would highly recommend video surveillance at every opportunity at your facilities. Without Nelson Brothers having the benefit of video surveillance in studying this incident, we may still be guessing at what exactly caused the explosion and fire and would not have had the pertinent information needed to help prevent it in the future.

Commented [HM4]: Could a video of the explosion b shared at the Congress presentation?

REFERENCES

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