

## Incident

# The sugar dust explosions and fire at Imperial Sugar Company, Georgia

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## Summary

In February 2008, a series of sugar dust explosions and a fire occurred at the Imperial Sugar manufacturing facility in Port Wentworth, Georgia, USA. Fourteen workers were killed and a further 36 injured. The facility housed a refinery that converted raw sugar cane into granulated sugar which was then transported by screw and belt conveyors into silos from which it was further transferred to sugar processing and packaging plants. The US Chemical Safety and Hazard Investigation Board (CSB) carried out an investigation into the accident, determined the causes of the primary and secondary explosions and identified a range of contributory factors. The CSB then made recommendations to Imperial Sugar Company, and to other bodies, aimed at rectifying any shortcomings and preventing a recurrence.

**Keywords:** Dust explosion

## Introduction

The first explosion initiated in the enclosed steel belt conveyor below the sugar silos (Figure 1) and was the result of explosive accumulations of sugar dust inside the enclosure. Poor housekeeping was a major contributory factor, and this is a feature that has relevance to any facility dealing with finely divided substances that might accumulate and be a source of explosion – due to static discharge or other reason(s). Severe damage was caused to plant equipment and buildings in addition to the loss of, or impairment to, life. The circumstances are described in detail in the CSB report into the accident<sup>1</sup> and summarised in this article.

## Background to and description of the accident

Imperial Sugar Company purchased the Port Wentworth facility in 1997 and in 2007 the company produced more than 1.3 million tons of sugar, making it one of the largest sugar refiners in the USA. More than 350 employees and contractors worked at Port Wentworth where annual average sugar production exceeded 700,000 tons.

Raw sugar was received and refined, then transferred by belt conveyor into a penthouse above the silos, then into the storage silos themselves (3 of). From the silos, the sugar was carried onwards to the bulk sugar truck and train loading area, the packing buildings and the powdered sugar production

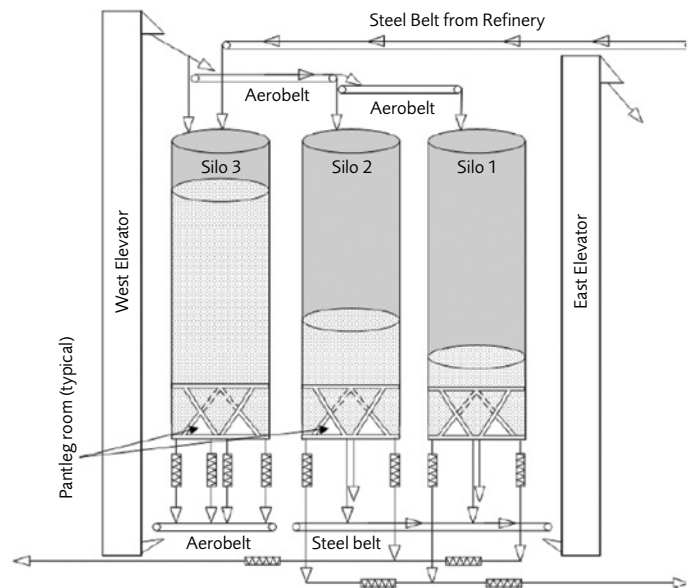


Figure 1: Sugar flow into and out of the silo

equipment in the south of the building (Figure 2). Packaged products were palletised and transferred to a warehouse for distribution to customers. Dozens of screw conveyors, bucket elevators and horizontal conveyor belts were used to move granulated sugar throughout the buildings. The bucket elevators were enclosed and the conveyors covered but not adequately enough to prevent escape of sugar dust into the open work areas. These areas were not equipped with dust extraction, so sugar settled readily on overhead piping, conduit, beams, lighting and general equipment.

The granulated sugar was stored and conditioned in the 105-foot (32m) tall, 40-foot (12m) diameter silos located on raised concrete foundations above the belt conveyors. Sugar entered Silo 3 and was then transferred to Silos 1 and 2. An 80-foot (24m) long steel conveyor belt was used to transport sugar from these silos to the downstream stages and, in 2007, a steel frame with top and sides was installed round this conveyor to prevent contamination of the sugar from debris that could fall into it. This enclosure was not equipped with dust extraction or explosion vents. It would transpire that this was a crucial factor in the initiation and propagation of the explosions.

At about 7.15 pm on 07 February 2008, a sugar dust explosion occurred in the enclosed steel conveyor belt under the granulated sugar silos. Seconds later, massive secondary dust explosions propagated through the entire granulated

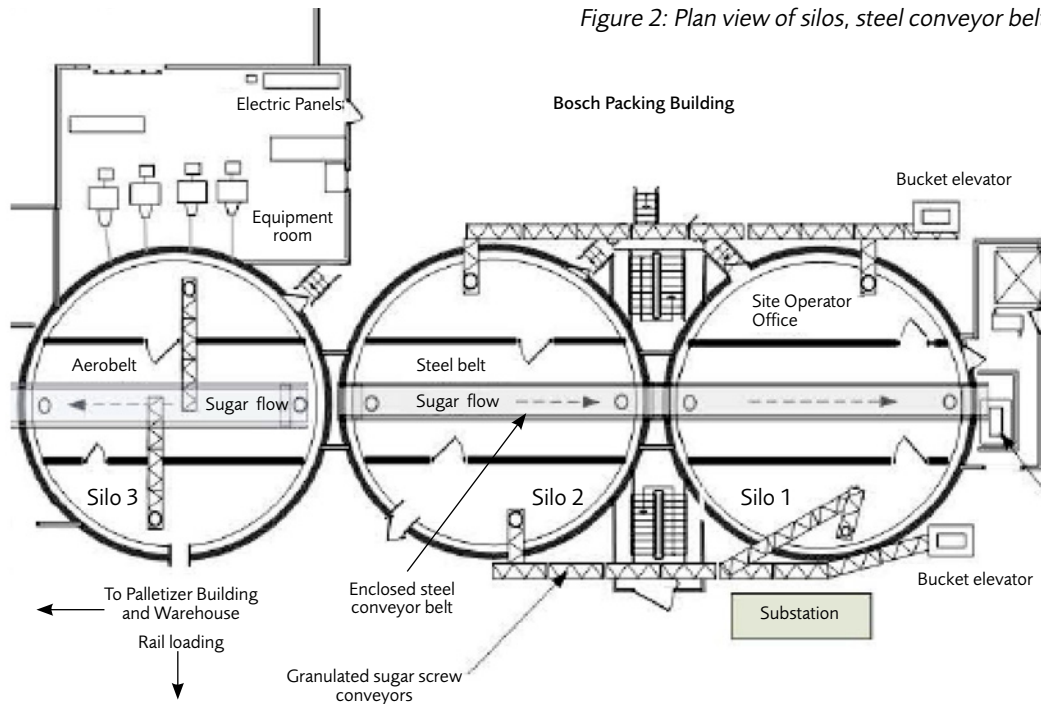


Figure 2: Plan view of silos, steel conveyor belt and other items

and powdered sugar packing buildings, bulk sugar loading buildings and the raw sugar refinery. Three-inch (75mm) thick floors buckled from the force of the explosions, the roof of the palletizer building was shattered and blown into the railcar loading area. Violent fireballs erupted out of the penthouse on top of the silos, the west bucket elevator and surrounding buildings (Figure 2). The damage to the silos and adjacent buildings is shown in Figure 3, and the extent of the devastation to the entire site is illustrated in Figure 4<sup>2</sup>.

The intense fireballs advanced through the entire north and south of the building as sugar dust ignited. Fire spread through the enclosed conveyors and caused more fires in the refinery and other buildings hundreds of feet from where the incident had begun. The fire water sprinkler system failed because the explosions ruptured the water feed pipes.



Figure 3: The damage to the south packing building and the penthouse

Eight workers were killed at the scene and six others died in hospital from the effects of serious burns. A further 36 injured workers eventually survived, but some of them had permanent, life-changing conditions. Approximately 85 other workers on site at the time of the accident were uninjured.

When local fire brigades arrived on the scene minutes after the first explosion, they were confronted by dense smoke, intense heat, ruptured fire water mains, buildings that were ablaze and large amounts of debris strewn about the site. The major fires were extinguished the next day but smaller fires burned for many days. The granulated sugar fires in the silos continued to smoulder for more than seven days before they were extinguished by an industrial firefighting company.

## Investigation of the accident

### The primary explosion

The investigation carried out by the CSB determined that the primary dust explosion initiated in the enclosed steel belt conveyor below the sugar silos. During more than 80 years of operation, sugar dust spilled into the tunnel under the silos but almost certainly never accumulated to concentrations above the minimum explosive concentration (MEC). This was because it was a large, open, well ventilated space. However, the enclosure of the tunnel, to prevent extraneous objects falling into the sugar, carried out a few months before the accident, materially changed this situation. The company did not evaluate the hazards arising from accumulation of combustible dust inside the enclosure. No dust removal system was installed and the system was not equipped with deflagration vents to release any overpressure arising from ignition of sugar dust.

Examination of blast patterns and damage inside the tunnel enabled CSB to conclude that the primary explosion probably occurred at about the midway point of the conveyor belt. Every



Figure 4: The extensive damage to buildings and equipment

panel had been blown off the tunnel support frame. There was major damage at the east end of the silo tunnel (Figure 2) with all equipment deflections eastwards away from the tunnel. The equipment under Silo 3, and outside the west of the tunnel, had damage patterns indicative of a pressure wave travelling west out of the tunnel. The wooden walls and doors were blown off both the east and west entrances of the tunnel. Mangled steel belt cover panels were blown off and the brick wall to the south was blown into the south packing area.

In the 3-4 days before the accident, sugar lump blockages in Silo 1 discharge holes were being cleared by use of steel rods. During these "rodding" operations, sugar continued to flow from Silo 2 onto the moving belt upstream of Silo 1 and this probably resulted in lumps of sugar lodging between the belt and Silo 1 discharge chutes. This would create a "dam" and cause sugar from Silo 2 to spill off the belt and this spilled sugar accumulated inside the unventilated enclosure and reached concentrations above the sugar MEC. A source of ignition caused an explosion that triggered a series of secondary explosions that rapidly progressed through the packing buildings, palletizer room and bulk sugar station.

### Potential sources of ignition

The actual source of ignition could not be precisely established. However, CSB considered several possible sources and came to the following conclusions. The minimum ignition temperature (MIT) of sugar dust clouds ranges from 360–420°C depending on the test apparatus used. Also, the MIT decreases with residence time in the environment tested. Airborne combustible sugar dust would almost always have been present inside the conveyor tunnel and be prone to ignition if the necessary temperature was reached. There was evidence that the steel belt roller support bearings sometimes got very hot. CSB concluded that contact of sugar dust with these hot bearings was the most likely cause of ignition. A possible, but less likely, source was friction sparking, while electric spark ignition was considered to be very unlikely. Open flames were ruled out.

### The secondary explosions and fires

The primary explosion sent overpressure waves out into the first floor of the Bosch Building (Figure 2). Brick walls were blown from the silo area into the packing area. Fireballs were fuelled by sugar dust dislodged from overhead equipment and thrown into the air by the advancing pressure waves. Concrete floors were violently heaved upwards throughout the south packing building. Workers in the packing buildings had little or no warning as walls, equipment and furniture were thrown into the air. Escape routes were hampered by dense, dark smoke. Intense fireballs advanced through the entire north and south packing and palletizer buildings. Fires were ignited in the refinery and bulk sugar building hundreds of feet away from the seat of the incident. The secondary explosions and fires most probably caused the fourteen fatalities.

### Housekeeping

The investigation established that sugar spillage and dust generation were constant problems. Leakages occurred from worn seals, loose equipment covers, breaches in the screw conveyors, bucket elevators and other items. The large work areas were not typically equipped with dust extraction systems, so sugar dust would float into the air and settle on overhead piping, lights and other horizontal surfaces. Regular cleaning was necessary in order to keep dust levels below dangerous (potentially flammable or explosive) levels but this was not done despite the efforts of the workforce with the inadequate means available to them. Written housekeeping schedules were not complied with.

A sugar dust extraction system was in place to remove dust from granulated sugar equipment and transfer it via ducts to dust collectors. Water spray removed the sugar dust from the air. A dry dust removal system was employed for the powdered sugar and cornstarch equipment. Regrettably, these systems were not functioning efficiently and were inadequately maintained. A report from an independent contractor less than a week before the accident noted:

- air extraction flows significantly below the minimum dust conveying velocity
- undersized fans — some operating below the required performance curve
- incorrectly installed duct piping
- duct piping blocked by sugar.

### Training

The company's "Specific Safety Rules" policy required that new workers should receive comprehensive safety rule training on the first day of employment supplemented by annual refresher training. A range of topics, including the hazards of dust accumulation, was covered but a review of the training records by CSB could find no evidence that this had been covered since 2005 — between two and three years prior to the accident. Documentary training sheets did not include information on combustible dust. Some two months before the accident (in December 2007) the US Occupational Safety and Health Administration (OSHA) issued its Combustible Dust National Emphasis Programme<sup>3</sup> and Imperial Sugar were aware of this. Yet, in January 2008, the company's *Written Program – Housekeeping & Material Storage Program* made no mention of combustible dust.

## Emergency plans and equipment

Within the refinery and packing buildings, workers had to rely on radios and cell phones to report or be alerted to an emergency. The emergency procedure directed them to use intercom but no such system was present in these areas. There were no visible or audible alarms.

No evacuation drills were practised, though evacuation routes were displayed. Emergency evacuation lights and exit signs were in existence but the explosions and fires caused many of them to fail. Thus, some workers had extreme difficulty finding their way out of the darkened buildings. As already stated, the emergency water sprinkler piping system was heavily damaged by the explosions. There were many fire extinguishers, including some on wheeled carts incorporating as many as 16 portable ones and these were effective for small to medium fires. However, against the major, rapidly advancing fires that ensued, they had little effect.

## Combustible dust characteristics

For the best part of a century<sup>4</sup> sugar dust has been recognised as an extremely combustible material. Tests carried out on samples of sugar and cornstarch from the Port Wentworth facility indicated that a primary explosion fuelled by airborne sugar dust would be very capable of causing the degree of damage that resulted from this accident. Accumulations of sugar dust on horizontal surfaces are a fire hazard. However, in order to ignite explosively, the dusts must become airborne and reach a concentration above the Minimum Explosive Concentration (MEC). A fireball will probably result when airborne dust at concentrations above the MEC comes into contact with an ignition source and the likelihood of explosion increases if the airborne dust is confined as in the enclosed conveyors. Increasing pressure inside enclosed equipment (pressure piling) can cause rupture of equipment or, if rupture does not occur, result in fireballs travelling considerable distances and igniting secondary fires far away from the initial ignition source. All this was totally consistent with the sequence of events that actually occurred.

## Conclusions

Stemming from their investigation, CSB came to the following conclusions:

- Imperial Sugar and the granulated sugar industry generally had been aware of sugar dust explosion hazards since 1925 but underestimated the hazard posed despite a history of near misses.
- The company had distributed the OSHA Combustible Dust National Emphasis Programme within the facility but had not acted promptly on its advice regarding removing significant sugar dust accumulations.
- The design and maintenance of the sugar and cornstarch conveyors did not minimise the release of sugar and sugar dusts into the work area.
- Whilst the importance of good housekeeping practices had been emphasised from as long ago as 1958, they were inadequate to control and minimise significant accumulations of sugar and combustible sugar dust throughout the packing buildings.

- Airborne sugar dust concentrations exceeded the minimum explosive concentration (MEC) inside the newly enclosed conveyor belts below Silos 1 and 2. Before the belts were enclosed, it was probable that the MEC would not have been reached because dispersion into the wider work area would have prevented this.
- The primary dust explosion was probably initiated by an overheating bearing in the steel conveyor belt; there had been previous fires caused in a similar way but all of them were very minor.
- The primary explosion triggered massive secondary dust explosions and fires throughout the packing buildings; the enclosed steel conveyor belt was not fitted with explosion vents.
- The secondary explosions and fires were the probable cause of the fourteen fatalities.
- Emergency evacuation plans were inadequate and the company had not carried out emergency evacuation drills prior to the accident.
- The independent audit carried out in April 2007 by a property risk insurer did not properly address combustible dust hazards.

## Other dust explosions

This accident was far from being an isolated case. The CSB report itself instances three other accidents in the USA, all in 2003, which between them resulted in a total of 14 deaths, many injuries and major plant damage. Furthermore, the CSB investigation report Combustible Dust Hazard Study (2006)<sup>5</sup> identified 281 combustible dust incidents between 1980 and 2005 that resulted in 119 fatalities and 718 injuries. This prompted CSB to recommend that OSHA should issue a comprehensive combustible dust standard for general industry and this was in progress at the time of the Port Wentworth accident.

In the UK, a major sugar dust explosion occurred in the sugar silo at the British Sugar Refinery in Cantley, Norfolk in July 2013. Although there were no fatalities or injuries, the damage to plant was extensive. The plant was shut down and undergoing maintenance at the time, when welding operations on the outside of the silo feed bucket elevator led to overheating of sugar coatings on the inside surface of the equipment. Molten metal penetrated through to the inside of the elevator casing and was a feasible cause of ignition of the sugar cloud present inside the elevator. The risk assessment carried out before work started was flawed in that it did not identify the potential for an explosive atmosphere inside the elevator<sup>6</sup>.

Then, in July 2015 the dreadful accident at the wood flour plant at Bosley, Cheshire occurred. Explosions and fire resulted in the deaths of four workers. Wood flour is another very finely divided substance prone to spontaneous ignition if not properly controlled and contained.

Against this background, the UK Health and Safety Executive provides guidance on the prevention of fires and explosions from dusts<sup>7</sup> and issues an information sheet specifically addressing Prevention of Dust Explosions in the Food Industry<sup>8</sup>. The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)<sup>9</sup> underpin the

need for assessment and protection of substances that could give rise to explosion or fire, and methods of prevention or mitigation.

## Recommendations

CSB made recommendations to Imperial Sugar and to other bodies aimed at addressing their findings. Principal amongst these were that Imperial Sugar should:

- Review all of their facilities against the terms of the National Fire Protection Association standards and other documents and implement any corrective actions identified.
- Implement a company-wide comprehensive housekeeping programme to ensure that combustible dust does not accumulate to hazardous quantities on horizontal surfaces, floors and equipment.
- Develop and implement training programmes for employees and contractors that address combustible dust hazards.
- Improve the emergency evacuation policies and procedures at the Port Wentworth facility.

In addition, recommendations were made to various external bodies to promulgate the investigation findings to a wider forum as appropriate. These included national and international organisations such as The American Bakers Association, The Sugar Association, Sugar Industry Technologists and American Institute of Baking International. Risk insurance companies were required to ensure that awareness of combustible dust hazards was fully understood.

## Author's comments

The CSB's recommendations, although certainly valid, do not seem to go far enough to respond to such a disastrous accident with the hope that a recurrence could be avoided. Other issues that might have been addressed included:

- The absence of an effective "corporate memory." The principle of building up a reference bank of accident and near miss data, and passing this on to employees, has been established for many years now. However, this was not mentioned.
- Systems for the management of change were certainly not strongly established unless CSB chose not to highlight them. Enclosing the conveyor belts was a significant change but it does not seem to have been subject to any risk assessment prior to implementation.

- OSHA were so concerned about the outcome of the accident, and the possibility of similar ones recurring, that they wrote individual letters to 30,000 workers employed in dust-producing operations warning them of the hazards.

The other distressing outcome of the accident, was that the refinery was closed down. Many of the damaged buildings had to be demolished and, although Imperial Sugar intended to rebuild the refinery and resume production, this proved to be uneconomical and was not done. The result of this was an economic depression in Port Wentworth, due not only to the loss of the refinery itself, but also the knock-on effects on many local businesses.

Relatively simple measures can sometimes yield large dividends. In this respect, a major British sugar-producing company eliminated, as far as was practicable, horizontal surfaces that sugar dust could settle and accumulate on. A triangular profile was installed on top of girders, purlins and other items thus enabling dust to slide off onto floors and other surfaces from which it could more easily be cleaned up.

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