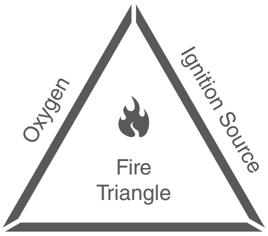
DOME TECHNOLOGY®

Countering Catastrophe

New Solutions for Managing and Preventing Silo Explosions

A dust explosion in a sugar plant in 2008 killed 14 people and injured dozens.

When Catastrophe Strikes



On February 7, 2008, a sugar packaging plant outside of Savannah, Georgia exploded. A clog in an enclosed conveyor belt caused a concentration of sugar dust to accumulate. When the dust came in contact with an ignition source, probably an overheated ball bearing, the explosion blew apart the enclosure. It also shook the buildings of the plant, causing built-up dust that had rested on lights, ducts, structural framing members, and other horizontal surfaces to shake loose into the air. This dust ignited from the original explosion, sending a series of blasts throughout the plant. In the end, brick walls and concrete floors were blown apart, fourteen workers lost their lives, dozens more were injured and the entire plant was destroyed.[1]

This kind of accident caused by dust explosions has happened before, including: February 1999 in a foundry in Massachusetts, January 2003 in a pharmaceutical plant in North Carolina, February 2003 in an acoustics insulation manufacturing plant in Kentucky. In a wide variety of industries, many were killed, many more injured, and all of them involved a series of explosions caused by dust.[2]

While these are extreme cases, many resulting in injury or loss of life, even smaller explosions can be catastrophic. These can lead to litigation, damaged structures, wasted product, halted operations, and damaged reputations. By understanding the causes, and bringing new solutions to bear, Dome Technology can help customers reduce the risk of similar catastrophes.

The Fire Triangle

The National Fire Protection Agency in the United States uses The Fire Triangle, also referred to as the Combustion Triangle, to educate about how fires start.[3] The three corners of the triangle identify what needs to happen in order for combustion to occur as well as for a fire to remain burning. Those three ingredients are oxygen, fuel, and an ignition source.

Oxygen is a naturally occurring gas in any storage environment due to the prevalence of oxygen in the air. This oxygen can be removed and replaced by more inert gases, such as nitrogen or carbon dioxide to reduce the risk of combustion. However, this is costly and poses additional potential hazards to personnel and passers-by. Removal of oxygen in a storage facility is not an ideal solution for most customers.

Sugar dust is highly combustible and poses a greater detonation risk.

In dry bulk storage, dust is the primary source for fuel in an explosion. Dust is released into the air when a material is handled, when it falls through the air to fill a silo, and when it is removed from the silo. While some dusts are more combustible than others, enough concentration of dust can fuel explosions. Dust that settles on flat surfaces, such as in the sugar plant referenced, can be shaken into the air from an initial explosion, becoming fuel for secondary explosions.

Understanding the properties of a stored material is critical. Some coals, for example, are volatile enough to catch fire during shipping. If uncaught and loaded into a silo this coal can ignite an entire pile.

The last requirement for combustion to take place is an ignition source. This can come from malfunctioning mechanical and electrical systems used to handle the product. It can come from metal debris that has accidentally fallen into the bulk material, or a multitude of other sources.

An indirect source of ignition can be self-heating product. There are a number of reasons why a product would self-heat. Change in moisture content, such as when dryer or moister material is added to a stable pile, can generate heat—especially in hygroscopic materials. Oxidation and aging of certain products can generate heat. Biological process, like decomposition, can be a source for self heating. The accumulative effect of these small reactions across many tons of stored material can cause a pyrolysis process to occur within the volume of the pile, or in other words, a low oxygen smoldering burn. When smoldering material in a pile is exposed to oxygen, an open fire can start, potentially igniting an explosion.

Eliminating just one of these components is enough to prevent an explosion. Taking measures to reduce or eliminate more is the surest method. However, the potential risks posed by some materials and conditions are cause for further safety measures. Taking these measures begins with an understanding of the difference between a deflagration and detonation.

Deflagration vs. Detonation

Not all explosions are created equal. A combustion that creates a high energy, high pressure shock wave is called a detonation. These are pressure waves traveling greater than the speed of sound and are more likely in environments containing highly combustible dusts, such as aluminum, magnesium and sugar, among others. A detonation has the greatest potential for destruction.

Lower energy combustions traveling at less than the speed of sound are called deflagrations. These are more common in environments containing less combustible dust from products such as grain, coal and wood pellets. Deflagrations,

High levels of combustible dust suspended in the air is a source for catastrophic explosions.

while not as destructive as detonations, still have enough energy to cause losses.

Deflagrations can cause or become detonations. Dust shaken loose from the structural members of a silo and other flat surfaces by the force of an initial deflagration can increase the concentration of dust in the air and thereby initiate a second more powerful event, a detonation. Also, deflagrations passing through dust in the air of long, barrel-like structures may experience enough back-pressure to transform into detonations.

Storage of less combustible material is not insurance against the potential for more destructive detonations. This fact should reinforce the importance of enforcing strict material handling practices when even a modest risk for combustion exists. The selection of the storage structure can also play a part in eliminating the opportunity for secondary explosions to occur, and mitigating the damage caused if they do.

A well ventilated conveying system, designed to reduce dust.

The Inadequacies of Traditional Structures

Not all structures are equally suited for reducing the risks of deflegrations and detonations, or reducing the damage caused should they still occur.

The traditional A-frame structure, for example, has a few inherent risks. These steel clad structures typically provide inadequate insulation from heat and moisture, which among other problems increases the propensity for ignition from fires started by inadequately managed self-heating products. The abundance of flat surfaces on steel support structures creates opportunities for the collection of combustible dust. This dust could become the fuel for a secondary explosion if unsettled. Steel paneling is often blown off by even minor explosions, creating shrapnel that can harm nearby structures, equipment, and people. All of these introduce risks that are costly to address or altogether unavoidable.

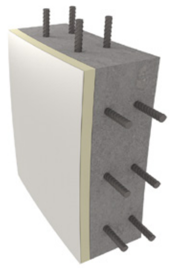
The cylindrical, concrete silo offers better insulation from heat and moisture than the typical A-frame steel structure. But because of its narrow and long shape it can amplify the effect of a pressure wave inside. A deflagration or detonation has only one path of travel in these structures, which is directly through the roof and mechanical equipment atop it, typically blowing these completely off. Furthermore, concrete is water permeable and susceptible to temperature fluctuations, which are factors in causing self-heating, which in turn increases the risk of an open fire breaking out if not properly managed. The steel roofs atop many cylindrical concrete silos introduce the same hazards as other A-frame structures, such as

A revolutionary construction process is central to the benefits the Domesilo has over traditional solutions.

dust accumulation. Measures can be taken to address some of these risks, but not all projects are viable with the additional time and costs involved in doing so. Fortunately a better structural alternative exists.

New Benefits Provided by the Domesilo

Over 30 years, Dome Technology has developed and refined an entirely new solution for storing bulk material, the Domesilo™. By its unique construction methodology, material composition, and shape, the Domesilo has intrinsic traits for reducing the risks of explosion and minimizing their impact should they happen.



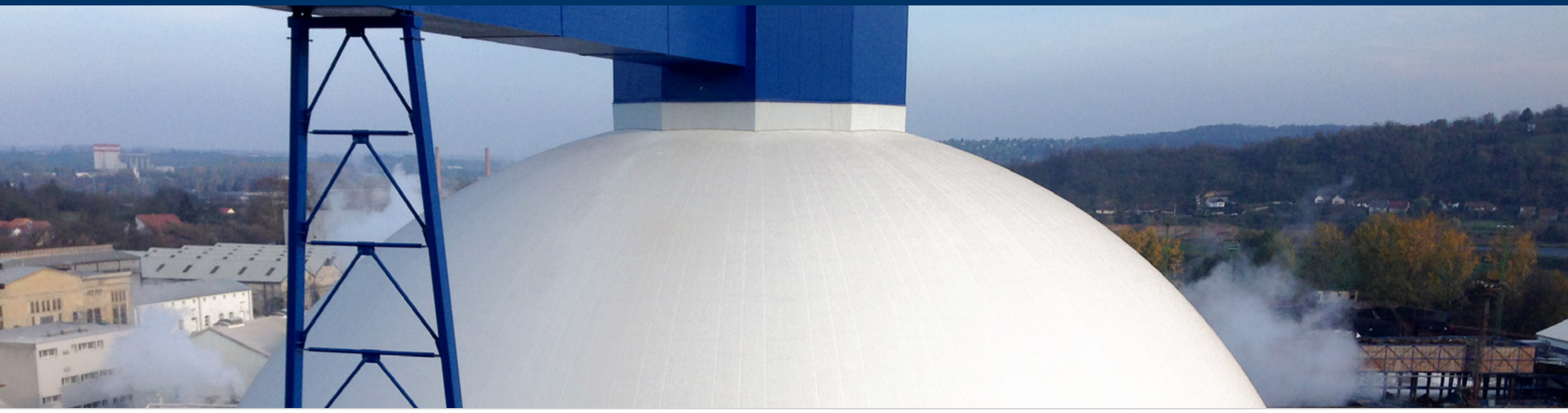
The three layers of a Domesilo: PVC waterproof membrane; polyurethane foam insulation; and steel-reinforced concrete.

A measure for reducing an explosion hazard is reducing self-heating in stored materials. An important part of this is creating a temperature and moisture stable environment. While other structural types vary in their ability to accomplish this, usually requiring costly add-on measures of varying effectiveness, the Domesilo has these properties built in, every time. This is because the Domesilo is built in a fundamentally different manner.

After the preparation of the foundation, the Domesilo is erected by a process that begins with the inflation of a PVC fabric form. From within this airtight and waterproof inflated membrane a layer of polyurethane foam insulation is applied. Subsequent layers of attached steel rebar and applied concrete form the super strong shell of the Domesilo which also acts as a thermal mass. The dome is built from the outside in. These layers working in tandem provide unparalleled protection from outside moisture and thermal fluctuations. In conjunction with safe material handling practices this enables far more efficient and effective management of self-heating within a product pile.

Well engineered ventilation can help reduce the dust suspended in the air in all structures, but dealing with the accumulation of dust on surfaces is more difficult. Fortunately the Domesilo offers unique benefits in this regard. The double-curvature shape and concrete composition of the Domesilo mean there are no steel beams for dust to accumulate atop. This leaves only the dust that can cling to the concrete itself. In this regard further surface smoothing measures can be taken when warranted by the risk. Though not guaranteed to eliminate all dust accumulation, the Domesilo offers many benefits for reducing it, thus reducing potential operating expenses necessary to eliminate this fuel for more destructive explosions.

Should safety measures be disregarded or an unforeseeable events lead to an



The Domesilo is unmatched in its intrinsic strength and integrated protection against heat, cold and moisture.

explosion, having a structure capable of reducing the impact of an explosion is critical. In this regard the Domesilo is innately superior to many traditional structures.

The steel-reinforced concrete shell of the Domesilo pairs the compressive strength of concrete and the tensile strength of steel with the strongest geometric form in the world. This monolithic, double-curvature shell distributes forces more evenly across the entire structure without the discontinuities or weak points that can more easily cause traditional silos to fail. As a result a Domesilo can withstand internal pressure of 0.6 bars or greater. Additionally its more uniform strength allows greater placement options for explosion venting, which means a pressure wave can often be directed away from critical superstructure. The Domesilo does not have the long barrel-like shape of many silos, thus avoiding the amplifying effects that can cause on a deflagration or detonation.

In providing both protection from a detonation and minimizing the effects of an explosion, the Domesilo is a uniquely capable alternative.

A new generation of storage structures with new explosion mitigating properties.

Progress Towards a Safer Future

Choosing a superior structure is an important part of explosion prevention, but it is not the only part. Performing a HAZOP analysis, practicing careful material handling, diligently monitoring conditions, and regularly maintaining a facility are vital parts of an overall strategy to reduce the risk of explosions in a storage environment. That being said, there has never been a more capable and attainable structural solution available as part of this strategy to reduce risk and minimize damage than there is now with the Domesilo from Dome Technology. In light of the potential consequences of catastrophe like the one that took place in Savannah, Georgia, and the enormous intrinsic value presented by a Domesilo, as far as the structure is concerned, there is no longer need for compromise.

1 https://www.youtube.com/watch?v=Jg7mLSG-Yws
2 https://www.osha.gov/dts/shib/shib073105.html
3 https://www.nfpa.org/press-room/reporters-guide-to-fire-and-nfpa/all-about-fire. A dust explosion pentagon was developed by the Occupational Safety and Health Administration (OSHA) in the United States,which provides an expanded framework for understanding explosion prevention. It can be found at https://www.osha.gov/dts/shib/shib073105.html.

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