

Grain Bin Entrapment and Engulfment – Causes, Prevention and Rescue

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Introduction

Grain bin suffocation accidents, from entrapment or engulfment, are reminders that grain storage, especially flowing grain, may become very dangerous. This fact sheet discusses crucial information related to grain entrapment and engulfment with extra focus on their causes, prevention and rescue. The term **entrapment** is used when a grain bin worker becomes buried in the grain beyond the point of self-extraction. On the other hand, the term **engulfment** is used when a grain bin worker is completely buried or submerged beneath the surface of the grain.

Available data from the University of Purdue shows that during the period 2007 to 2015, the total number of reported grain entrapments reached 307 cases, as shown in Table 1. The highest and lowest grain entrapment numbers of 57 and 19 were in the years 2010 and 2012, respectively. During the last reported three years, i.e., 2013, 2014 and 2015, the number of nonfatal cases represented 20, 21

and 10, respectively. The number of fatal cases due to grain entrapment were 13, 17 and 14, respectively, during the same three years. Unluckily, in many cases, grain entrapment leads to engulfment, which is always fatal. The fatal incidents to total incidents ratio, unfortunately, represented 47.6 percent of the entrapped cases. Rescue operations were rarely successful for victims who were fully engulfed in grain. Consequently, more public awareness is needed to prevent such incidents from flowing grain activities, as many, if not all, are avoidable.

Flowing grain is a term that is used to describe the movement (downward and out) of grain from a storage bin. During unloading, grain flows in a funnel-shaped path downward to the unloading auger (see Figure 1). A conveyor at the bottom of the bin transports the grain out of the bin. This vortex of grain behaves very much like a water whirlpool. Grain velocity increases as grain flows from the bin wall at the top of the grain mass into a small, vertical column at the center of the bin.

TABLE 1. The number of nonfatal and fatal incidents related to grain entrapment in the United States (adapted from Issa and Field, 2015)

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Nonfatal	15	17	22	26	19	11	20	21	10	161
Fatal	16	17	19	31	11	8	13	17	14	146
Total	31	34	41	57	30	19	33	38	24	307
(Fatal/Total)	51.6%	50.0%	46.3%	54.4%	36.7%	42.1%	39.4%	44.7%	58.3%	47.6%

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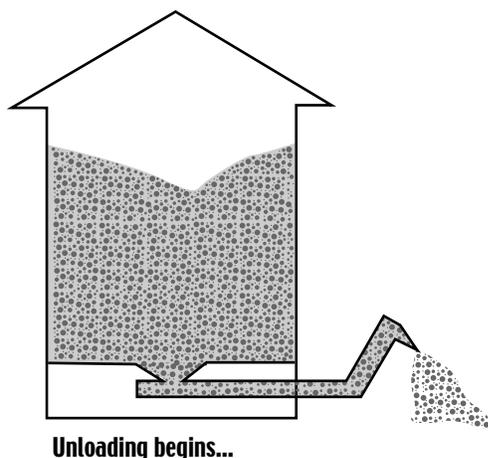


FIGURE 1. As grain leaves the outlet, grain directly above the opening flows down without stoppage. A continuous column of grain moves from the top surface to the bottom outlet.

If a worker is pulled under, there is often little or no time to react. Rate of inflow at the center top of a grain bin is so great that escape is impossible (Figure 2). Once engulfed in the grain flow, a worker is rapidly drawn down toward the bin floor. The rate at which grain is removed with the unloading auger or by gravity discharge from a valve makes engulfment more likely than many grain workers may realize. Bin unloading augers typically move grain from farm storage at the rate of 2,000 to 10,000 bushels per hour. At the slower 2,000 bushels per hour rate, this is approximately 41 cubic feet of grain moved per minute. Assume that a grain worker is 6 feet tall, which is roughly 7.5 cubic feet in volume. At 41 cubic feet of grain movement per minute, a grain worker, in rapidly moving grain, would not be able to free himself/herself after 5 seconds elapsed (Figure 2). The entire body of a 6-foot-tall person can be covered with grain in 11 seconds.

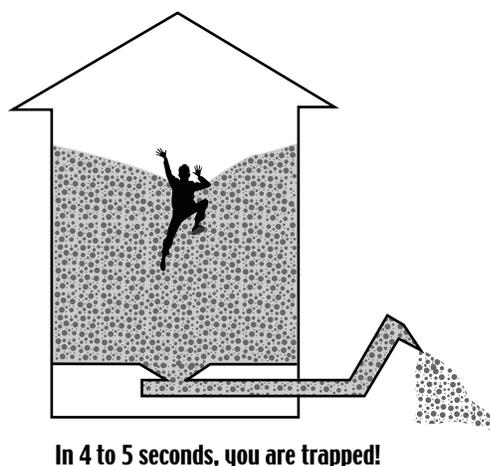


FIGURE 2. Entering a bin while grain is being removed may be a fatal mistake. Measurements with mannequins indicate that an adult may be engulfed in 11 seconds and, without immediate rescue, suffocate.

Reasons for Entering a Bin

- Grain workers monitor stored grain regularly. They may enter a grain bin or send someone to visually check the grain or feed condition. A worker may probe grain bins to determine if grain moisture is low enough for safe storage.
- Grain workers may attempt to detect “hot spots” or heating due to moisture migration, poor air flow distribution or pest activity where broken kernels have accumulated.
- Grain workers enter the bin to verify that new (and possibly stored) product will be preserved in the bin environment.
- Grain workers may be curious and enter grain bins to attempt to dislodge the grain because a grain cake or bridge may hinder grain flow out of the bin.
- Grain stored for seed may be inspected or sampled regularly for its viability.
- Children may enter a storage bin to play, or a trespasser may seek shelter.
- Someone may need to completely empty, clean the interior or spray insecticides in the bin.

Don't make the mistake of your life. Be aware of the dangers of flowing grain or feed.

Flowing Grain Hazards

Flowing grain is very dangerous. When the valve centered under the bottom of the bin is opened or the bottom-unloading auger is energized, grain or feed flows to the outlet. Grain directly above the outlet replaces the discharged grain. This downward flow pattern immediately transmits to the top grain surface, starting a column of flowing grain. Very little grain volume moves within the bin. The grain across the bottom and away from the center of the bin does not move. The velocity of the center column of grain leaving the bin depends on the size of the opening and/or the conveyor capacity. The weight of a person standing on the grain forces the grain supporting him or her to flow to the outlet rapidly. This person's weight creates an extra force that adds velocity to the grain underfoot and increases the speed of the sinking victim.

Grain may seem like flowing water in that it exerts pressure over the entire surface of any submerged object. However, the amount of force required to pull someone up through grain is far greater than to rescue someone from under water. In fact, water has a buoyant force that “floats” ships and assists lifeguards in rescuing victims much larger than the lifeguard. Grain is much different.

The predominant force is due to individual grains rubbing together to create a large friction force. The total forces resist anyone trying to remove a buried victim. Those who have rescued children partially covered with grain were surprised at the amount of energy required. Typically, grain resistance pulls a person's shoes off when he or she is drawn out. Research shows that more than 900 pounds of pull is required to raise an adult mannequin covered with wheat or corn. In essence, all but very well-prepared and well-equipped rescues are doomed to fail.

In one instance, a grain farmer entered the wet holding bin that feeds the grain dryer, the dryer started automatically and he was drawn into the wet grain and suffocated. Another reported accident involved an elevator worker who entered a bin to break up a vertical pile of grain that would not flow. When the worker dug into the base of the pile, he was covered in an avalanche. He suffocated under only 12 inches of grain. He could not get up, since each square foot of his body was covered by a cubic foot of grain weighing nearly 50 pounds. In another case, a farm employee was using a high-capacity grain vacuum to suction grain from a grain-storage structure. He placed the vacuum hose inlet at his feet and was soon drawn into the grain as the grain was removed from beneath his feet. The employee was engulfed and suffocated before the machine could be shut off.

It should be mentioned also that airborne grain dust, microbial spores and inadequate oxygen to sustain breathing can cause the death or sickness of a person entering a grain bin (confined space). Persistent exposure to these airborne particles may cause "farmer's lung," which may lead to an irreversible lung condition, eventually causing death. Flowing grain hazards plus mold and dust health hazards may exist when working with grain that has gone out of condition or has bridged into a precarious stack. Those who enter should wear NIOSH-approved dust filtering respirators to protect their lungs. Other more effective filtering equipment may prove to be a better alternative for extended exposures.

Causes of Grain Entrapments and Engulfment

There are some major reasons that might contribute to grain bin entrapments and engulfment.

Collapse of Horizontal Crusted Grain Surface

Entrapment and suffocation can happen when a grain worker enters a bin in which the surface of the grain has become caked or bridged because of spoilage (Figure 3). The surface appears solid, but a thin crust covering a void may have formed as the grain is removed (Figure 4). When the worker breaks

the crusted surface, he or she will be quickly entrapped in the avalanche of grain collapsing into the cavity (Figure 5). Often the unloading equipment is still operating, which causes the worker to be pulled even deeper into the grain mass.

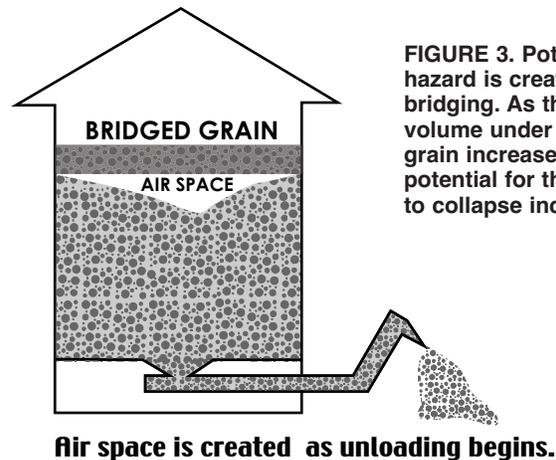
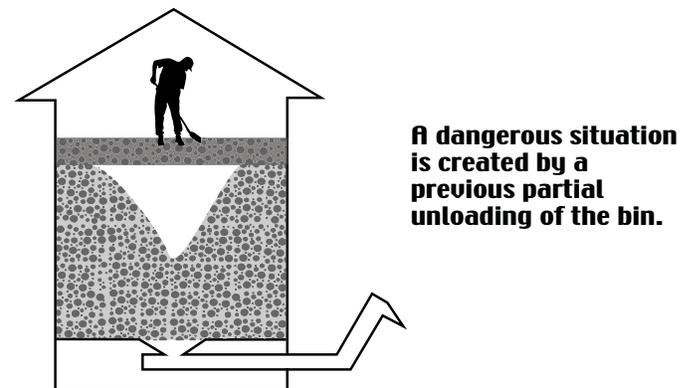


FIGURE 3. Potential hazard is created by bridging. As the hollow volume under bridged grain increases, the potential for the grain to collapse increases.



A dangerous situation is created by a previous partial unloading of the bin.

FIGURE 4. It appears that up to four basic principles were violated: (a) No co-worker is present when attempting this hazardous task. (b) The grain worker entered the bin without a safety harness or lifeline manned by co-workers. (c) He or she doesn't know or fails to recall the bin unloading history. When grain doesn't discharge from the unloading auger, be wary! (d) He or she may not have followed a "lock out/tag out" measure or failed to keep the key in his/her pocket to prevent someone from starting the unloading auger.

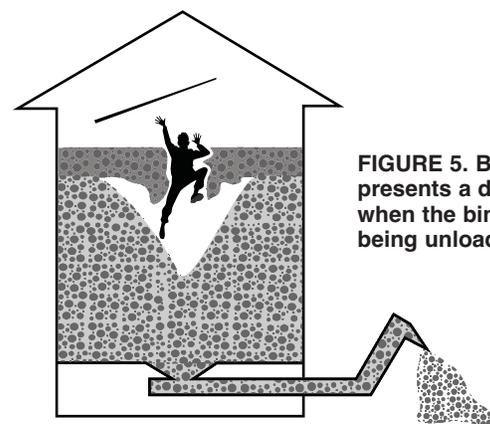


FIGURE 5. Bridged grain presents a danger, even when the bin is not being unloaded.

It may very well result in a break through to disaster...

Collapse of Vertical Crusted Grain Surface

Dry grain in good condition would pile at about a 30-degree angle. On the other hand, spoiled or caked grain can stand almost vertical. As grain is removed from the bottom of a caked pile, the potential for an avalanche and engulfment increases (see Figure 6). This type of entrapment can occur inside bins where the spoiled grain is clinging to the bin walls. Attempting to remove these masses of grain from the bottom using a long pole can be extremely dangerous. In an incident, farmers have been buried beneath a collapsed wall of freestanding grain.

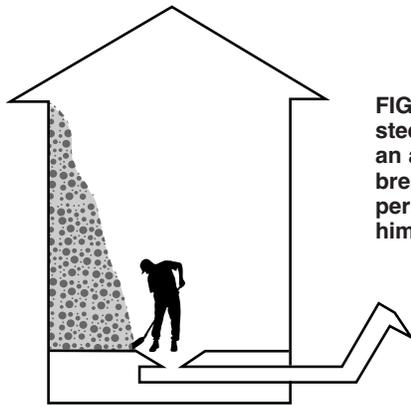


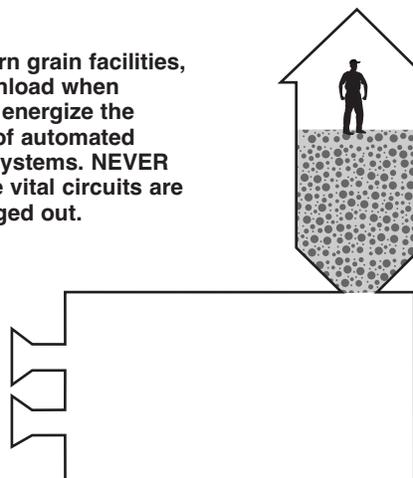
FIGURE 6. Beware of a steep wall of grain. Like an avalanche, it can break loose and force a person down, covering him or her with grain.

Beware of a steep pile of grain...

Entrapment in a Flowing Column of Grain

Entrapment or suffocation most often occurs when an individual enters a bin during the unloading process and is drawn into a flowing column of grain. As the bin empties out the bottom, a rapidly moving column of grain forms over the outlet. As mentioned earlier, this vertical column of grain acts like a fluid, and it flows down through the grain mass at nearly the rate of the unloading auger (see Figure 7). The rate of inflow at the center top of a bin is so great that once a person is trapped in the flow, escape is impossible. Once engulfed, the victim is

FIGURE 7. In modern grain facilities, bins may load or unload when automatic controls energize the circuits. Be aware of automated controls for grain systems. NEVER enter a bin until the vital circuits are locked out and tagged out.



Inspecting grain in the wet holding bin during the drying cycle...

rapidly drawn to the floor of the bin. The potential for becoming entangled with the bottom-unloading auger is also a possibility.

Entrapment or Suffocation in Grain Transport Vehicles

There is a risk of entrapment in grain transport vehicles such as wagons and trucks. Most cases involve trucks equipped with grain beds or gravity dump wagons in which the victims were riding. With the high-volume capacity of many on-farm storage facilities, grain workers could be covered over in seconds during an unloading operation. Unfortunately, many of the victims of this type of suffocation have been children. Some of the reported deaths involved a wagonload of grain that flipped over onto the operator during unloading. This resulted when crusted grain stacked up on one side of the wagon, causing the unit to become unbalanced.

Tips to Prevent Entrapment and Engulfment

Providentially, flowing-grain entrapment and suffocation are preventable. Following are major safety instructions that might protect grain workers and others:

- Try to alleviate any grain flow problem without entering the grain bin, if possible. Do not enter the bin without following all accident prevention measures, having a trained crew and using the recommended equipment.
- Do not work alone when monitoring or moving grain, even if only for short periods.
- Do not overlook the necessity of having an accident response plan that is understood by everyone before a person becomes engulfed in feed or grain.
- Discuss the safety hazards of grain dryers and bins and feed handling and storage facilities with your family and employees.
- Make specific accident response plans with employees and anyone who frequently works around the facility, such as a trucker. By working together as a team, more of the dangers will be identified and more practical remedies will be taken. If you use a team approach, the potential of entanglement or suffocation is almost eliminated.
- Wear a body harness tethered to a lifeline that is manned by two others outside the bin before entering a grain or feed bin. One worker should be able to see the worker inside the bin through an access. This support crew can retrieve the one who entered the bin. One rescuer can get aid, if

necessary, after the victim is retrieved, while the other is treating the victim (see Figure 8).



The worker on the ground can go for help or assist in pulling.

FIGURE 8. Follow your accident response plan. Make adjustments to fit the circumstances of the rescue without putting yourself or others in harm's way. The first rule of rescue is to avoid becoming a second victim, doubling the demands on others. Take the proper precautions the first time. You may not have a second chance.

- Do not depend on being able to be heard from the inside to the outside of the bin. The use of prearranged arm and hand signals is one suggestion for these conditions. It is difficult to hear under any circumstances, but especially when grain handling or drying equipment is operating.
- If you drop a grain probe or shovel, first stop the flow of grain, take the precautions, then retrieve the lost item. Remember, no piece of equipment is worth a human life (Figure 9).

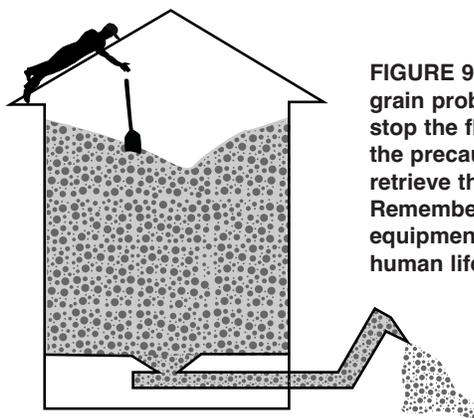


FIGURE 9. If you drop a grain probe or shovel, first stop the flow of grain, take the precautions, then retrieve the lost item. Remember, no piece of equipment is worth a human life.

The shovel was accidentally left in the bin...

- Learn about a grain bin's history before entering. Get help if the grain surface appears moldy or caked. Strike the grain surface hard with a pole or long-handled tool before entry. Probe through the top layer and determine if there is a crusted surface; never get out of communication with your co-workers.

- Do not fail to lock out/tag out related power equipment before entering any bin. It may also be wise to post a sign on the control box if it is possible that others may arrive after you padlock the control levers. If a bin is unloaded by gravity flow, padlock the control gate to keep it closed. Padlocks are readily available for this purpose at local electrical supply businesses. OSHA 29 CFR 1928.57 regulations require employees to follow this procedure.
- Have appropriate breathing apparatus if the victim has been unable to get sufficient oxygen or has been breathing air containing grain toxins. Use adequate dust protection.
- Preventative safety measures should include proper ladders, scaffolds, etc. Modern bins have an interior ladder, and these can be installed in older bins.
- Keep children off grain vehicles and out of bins while unloading and loading. Forbid them to play in hopper wagons and truck grain beds. Grain flow can cover them quickly before they realize what is happening.
- Beware of steep or crusted piles of grain. Dislodge them from above, if possible, with a long pole rather than with a short shovel.
- Do not rely on a rope, chain or pipe ladder hanging from the roof. They are not reliable and may obstruct flow during filling or increase drag during unloading.
- Do not enter a bin while the auger is operating because it is very dangerous. There is no reason to enter a bin with an auger engaged. A slip near an auger with grid covers removed, whether it is caused by flowing grain or a misjudgment, may result in a traumatic entanglement. Always advise others of your intentions before you enter a bin.

If it is essential for a person to enter the bin, he or she should wear the proper full body safety harness and a tether manned by others outside.

Tips to Rescue an Entrapped Victim

In the event of a flowing-grain entrapment, the following steps should be taken:

- Shut off all unloading equipment.
- Call 911 or emergency rescue services.
- Prevent anyone from entering the scene until trained emergency first-response personnel arrive.
- Turn on the aeration blower, if the bin has any, to increase the airflow through the bin to help the trapped person breathe.

- Assemble equipment for assistance with a rescue, including front-end loaders, shovels, plywood for coffer dams and portable augers.
- If you should become trapped in a grain bin or silo, stay near the outer wall and keep moving. If necessary, you can walk until the bin is empty or the flow stops.
- Seek help immediately. Getting help and successfully being rescued is much easier if you have an accident response plan. Contact your help waiting outside the bin.
- Do not attempt to winch a person from grain if the person is buried deeper than knee deep. This may cause joint dislocation, paralysis and other severe injuries.
- Remove the grain from around the person to get him or her out. You can do this by cutting holes in the side of the grain bin or by creating a cofferdam around the person and bailing out grain with a shop vacuum or a bucket. Grain cofferdams can be constructed by driving sheets of plywood around the person. They can also be constructed out of plastic barrels. Currently, there are several commercially available grain rescue tubes with interlocking pieces that are

connected and driven into the grain to create a cofferdam. Commercial rescue tubes typically have steps on the inside to assist the victim in climbing out of the grain.

For Further Reading

- Grain Bin Hazards, National Ag Safety Database. <http://nasdonline.org/71/d001694/grain-bin-hazards.html>
- Grain Bin Safety. University of Nebraska – Lincoln. https://ehs.unl.edu/sop/s-grain_bin_safety.pdf
- Grain Entrapment Prevention Initiative, GEAPS Chapter – December, 2011. www.grainentrapmentprevention.com
- Grain-Farm Safety. <http://farmsafety.mo.gov/safety-topics/grain>
- Issa, S., Y. Cheng and B. Field. 2015 Summary of U.S. Agricultural Confined Space-Related Injuries and Fatalities. https://extension.entm.purdue.edu/grainsafety/pdf/Space_Confined_Summary_2015.pdf
- Occupational Safety and Health Administration. Grain Handling. <https://www.osha.gov/SLTC/grainhandling/>

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