Frequently Asked Questions About Flowing Grain Entrapment, Grain Rescue and Strategies, and Grain Entrapment Prevention Measures[1]

The following are selected and edited questions that have been frequently asked concerning the problem of flowing grain safety and related topics. The responses are based upon current best practices and there is no claim that they comprehensively address every question or reflect the best solution or strategy for any specific situation. The questions and responses have been categorized under the general areas of "Grain Entrapments and Engulfment", "Grain Rescue Strategies", and "Grain Entrapment Prevention Measures".

1. Grain Entrapments and Engulfment

1.1. What is the difference between a grain entrapment and a grain engulfment?

An entrapment occurs when a victim becomes buried in grain beyond the point of self-extrication, while an engulfment is an incident where the victim is completely buried or submerged beneath the surface of the grain. Approximately half of grain entrapments lead to engulfment which in turn are almost always fatal.

1.2. Who are the most common victims of grain entrapments and engulfments?

Historically, approximately 75% of all documented victims of grain entrapment and engulfment have been farmers, farm employees, and farm family members. More recently, there have been a slightly growing percentage of victims who are employees of commercial grain storage and handling facilities. Almost all incidents have involved adult males, with exception of suffocations in grain transport vehicles which have been predominately male children between the ages of 10 and 15.

1.3. What types of grain have been involved in grain entrapments and engulfments?

Entrapments and engulfments have been documented in a wide variety of grains, including corn, soybeans, oats, wheat, flax seed, and canola. The majority (over 50%) of documented cases have involved corn.

[1] Many of the questions included have been used with permission from the Liberty Grain Rescue System® User's Manual, Edition #6, 1/11.

1.4. Why are more cases of grain entrapments and engulfments documented in the Corn Belt than other regions of the country?

Entrapments and engulfments occur where most of the grain is grown and stored. Therefore, more cases are reported from states such as Indiana, Iowa, Illinois, Minnesota, and Ohio where there are large acreages of corn and soybeans, and substantial on-farm storage capacity. Because of storage issues related to corn, including the high humidity of the region, more cases have been documented in corn than in any other type of grain. Relatively few cases are seen in the Upper Midwest or western states where the humidity is lower and more small grains are grown.

1.5. Why do more entrapments occur on farms than in commercial operations?

Farmers have a greater risk due to a number of factors including:

- Farmers tend to work alone and have no backup in the event of an entrapment.
- Farmers are not required to comply with federal confined space safety regulations.
- On-farm grain management practices may lead to more out-of-condition grain.
- Farmers handle less grain, and only at certain times of the year that may lead to more mistakes and unsafe practices.
- Farms are also the family home which may increase the risk to children living there.

1.6. Why has Indiana documented more grain-related entrapments and engulfments than any other state?

Purdue University has been documenting grain entrapments and engulfments since the late 1960's. It is almost certain that some states, such as Illinois and Iowa, that produce more grain, have actually had more incidents but they were undocumented. Indiana has reported more cases because more have been documented due to more aggressive data collection efforts. In 2010, Illinois and Minnesota reported the most number of incidents. Better surveillance techniques, such as on-line searches, have helped make more recent data collection more comprehensive.

1.7. What is the Purdue Agricultural Confined Space Database?

Purdue University began documenting cases of grain entrapment and engulfment in the late 1960's. This data was eventually entered into a computer database. In the

1990's the database was expanded to include incidents involving manure storage and handling facilities. Current efforts are underway to expand the database to include all types of agricultural-related confined spaces. Currently over 1,200 cases have been documented including almost 900 in grain storage and handling facilities.

1.8. Is the problem of grain entrapments and engulfments getting worse?

Yes. Over the past 20 years the number of grain-related entrapments and engulfments on farms and commercial facilities has been gradually increasing. Unlike most other types of agricultural-related fatalities and injuries, entrapments and engulfments have been increasing. A new record for documented entrapments and engulfments occurred in 2010 with 51 individuals, of whom 50% died.

1.9. What is contributing to the increased number of documented grain-related entrapments and engulfments?

There are several factors that are contributing to more documented cases. These include:

- Better incident reporting by the media and governmental agencies.
- Increased crop yields due to new production practices and technology.
- Larger volumes of grain are being harvested, handled and stored.
- Larger capacity storage facilities on both farms and commercial facilities.
- Larger capacity handling systems.
- Climate conditions that have increased the amount of out-of-condition grain in storage.
- Aging storage facilities that fail to adequately protect the stored grain leading to spoilage and difficulty removing the grain from storage.
- New generation of employees who may not recognize the threats associated with grain storage and handling.

1.10. Why does out-of-condition grain contribute to an increased risk of entrapment?

Grain that has not been dried properly will begin to spoil and form crusting or large clumps of grain glued together by the mold and spoiled material. This crusted material can prevent the grain from flowing freely and causes plugging at outlets. To maintain flow through the outlets workers will enter the grain storage structure and use long pipes to reach the outlet to break up the crusted material. This may expose

them to crusted surfaces covering voids or sudden flows of grain that are nearly impossible to escape from. (See www.grainquality.org)

In addition, crusted material can stick to the walls of the storage structure. A worker who attempts to break the crust from the wall from below can be buried under an avalanche of grain from the wall.

1.11. Do OSHA workplace safety standards apply to on-farm grain storage?

No. Grain storage structures located on farms or feedlots are currently exempt from most OSHA safety rules. This exemption also covers feed storage structures. However, if the farmer operates a commercial grain storage facility; his employees are covered by the OSHA standards. In some cases, farmers with more than 11 employees or who provide migrant worker housing may also have to comply with OSHA workplace safety rules.

1.12. Are children allowed to be employed in grain storage structures?

No. Under the Agricultural Hazardous Occupations Order, children under the age of 16 are prohibited from being assigned to work inside any confined space, including grain bins and silos. (See www.farmsafety4youth.org)

1.13. What is meant by walking down the grain?

This once widely used practice consisted of putting one or more workers inside of a grain storage structure to clean crusted grain off the inside walls and to break up crusted grain to prevent plugging. This practice is now illegal under the OSHA Grain Handling Standard.

1.14. Are grain bins classified as confined spaces?

Yes and No. Technically, grain storage bins meet the criteria for being classified as a confined space. Under the current OSHA Standards, however, grain storage structures on farms are exempt from complying with the confined space standards. The same structures at a commercial facility or industrial setting are classified as confined spaces.

1.15. How fast does it take to become engulfed in flowing grain?

Just seconds. With today's high volume grain handling equipment, a victim caught in a column of free flowing grain can be completely buried in less than a minute. A victim has little time to respond before escape becomes impossible.

1.16. What types of injuries do victims of grain entrapment and engulfment experience?

Most victims of full engulfment in grain die of asphyxiation due to ingestion of grain in the mouth, throat, and nose. Non-fatal injuries that have been documented include exposure to toxic dusts; hypothermia - from long term exposure to chilled, wet grain; entanglements in unloading augers; impact injuries from being struck by falling chunks of grain or falls into the storage structure; and limb dislocations due to attempts by rescuers to pull victims from grain.

1.17. Can suffocations occur in grain transport vehicles?

Yes. There have been numerous cases of both entrapment and engulfments in gravity flow grain wagons, semi and straight grain trucks, and railroad cars. The majority of these cases have been historically children.

1.18. How can the use of a grain vacuum machine lead to entrapment?

With the increased use of grain vacuum machines to handle grain there have been cases documented in which the victim, using a hand held vacuum inlet pipe, was pulled into the grain and suffocated. This type of entrapment occurred when the inlet tube was placed near the feet and began to remove the grain underneath the victim. Within a few seconds the victim is pulled in beyond the point of escape. The vacuum unit is so powerful that it's difficult to choke or slow the flow, and some inlet tube assemblies are not equipped with a means to shut off the flow at the operator station.

1.19. Can a life line and harness prevent entrapment or engulfment in flowing grain?

Yes, and No. If used properly an adequate anchor point, a life line and harness used in conjunction with an outside observer provide important measures of safety. However, a life line and harness used without the other required prevention measures provides little protection. There have been numerous reported incidents in which the victim entered an unsafe situation alone, tied off with life line and harness, but who still suffocated. The only value of the life line was that it identified the location of the victim beneath the grain surface. Life lines require a second observer with the ability to maintain tension on the line while the user is inside the space.

1.20 Are there adequate anchor points on a typical farm grain storage bin to secure a lifeline or provide a rescue anchor point?

No. Almost all on-farm bins were designed to store grain, not to provide adequate anchors to meet the current confined space entry regulations. Roof components or bin ladders are not designed to provide sufficient anchor points and could fail if overloaded. There are efforts underway to develop equipment to retro fit current grain storage structures to provide adequate anchor points. In some cases, trained first responders can rig adequate, anchor points that are on the ground, outside the structure.

1.21 Is the air inside a typical grain storage structure toxic?

Most often, no. Grain that is properly dried and stored does not produce toxic gases. The exception would be where grain has been stored too wet, above 14% moisture content, and carbon dioxide is released as the grain ferments and spoils. Wet storage bins used to increase the capacity of grain drying systems can also have carbon dioxide present if the grain is allowed to stay in the bin too long.

1.22 Is the dust in a grain bin toxic?

Yes and No. Grain dust is not considered toxic to most people but can cause respiratory distress, especially if the dust contains mold spores or other biological agents. Some molds found in grain are considered toxic to both humans and animals. If there are high levels of dust in suspension, the use of respiratory protection is recommended. (See www.grainquality.org)

1.23 Why do such a large percentage of grain entrapment victims end up suffocating?

Many of the documented incidents indicate that the majority of victims were working alone at the time of entrapment or that the observer was so far from the controls that the unloading process could not be shut off quickly enough to prevent complete engulfment. Once caught in the flow of grain it takes only seconds until the point of self-extrication becomes impossible.

1.24 Can engulfment occur outside of a storage structure?

Yes. Cases have been documented in free standing piles of stored grain and where storage structures have failed allowing grain to avalanche out covering nearby workers.

1.25 Why are grain entrapments and rescue techniques currently being studied?

Prior studies conducted by Purdue University's Agricultural Safety and Health Program (PUASHP) have identified a gap in the research related to grain handling, transport and storage, as well as rescue strategies. For over 30 years, data has been collected and nearly 900 cases of grain entrapments and engulfments have been documented. The overall objective is to identify the hazards associated with grain handling, transport, and storage, and reduce the associated risks through education efforts for farmers and professional grain handlers and training for first responders. The PUASHP staff also provides assistance to the grain industry in formulating engineering standards and to government agencies for regulatory issues.

1.26 How does the agricultural industry compare to other industries, in terms of fatalities?

Agriculture has the highest death rate, with 29 fatalities per 100,000 workers (Nation Safety Council *Injury Facts,* 2010 Edition). This is ten times higher than the fatality rate for all other industries. While most industries have experienced a declining trend with respect to their fatality rate, agriculture has remained fairly constant, and has been consistently ranked as one of the top three most hazardous occupations.

1.27 How do grain engulfments and entrapments compare to other agricultural incidents?

Grain entrapments and engulfments account for only a small percentage of on-farm incidents. For example, the PUASHP reported that from 2000 to 2009, there were 198 documented on-farm fatalities in Indiana. Tractor incidents accounted for 86 fatalities (43.4%), while grain engulfments and entrapments accounted for nine fatalities (4.5%). The Ohio Commission on the Prevention of Injury reported that from 1993 to 2002, there were 250 documented fatalities in Ohio. Tractors incidents accounted for 147 fatalities (58.8%), while grain bins and grain wagons accounted for 10 fatalities (4%). It is likely that the number of non-fatal grain-related incidents is 20%-30% higher, since many incidents go unreported when self-extrication is possible, but the total number is still a small fraction of the total number of agricultural incidents. And while the overall trend of on-farm fatalities is decreasing, grain related fatalities has been increasing.

2. Grain Rescue Strategies

2.1 Where is an entrapment or engulfment victim most likely to be located in the grain mass?

In most cases the victim, even if fully submerged, will be located directly below the center of the funnel shaped surface of the grain or directly over the outlet from which grain was being drawn at the time of entrapment.

2.2 Why is it important for first responders not to enter a structure immediately upon arrival at the scene if the victim is partially buried?

The victim will usually be at the bottom of the indentation formed in the grain surface, well below the upper levels of the grain. Entering the structure can cause the grain to cascade down onto and possibly covering the victim.

2.3 If a victim is fully engulfed, should it be assumed that a fatality has occurred and the process of recovering the body should begin?

No. Fully engulfed victims have been known to survive for a few hours – especially when there were air pockets between spoiled clumps of grain or the victim was able to cover his mouth and nose. This scenario if very rare however.

2.4 Will the weight of the grain on a partially entrapped victim prevent him from breathing?

Generally no. It is not the pressure of the grain on the victim that suffocates the victim, but rather the grain that obstructs his air way. Victims, however, can feel the increased pressure of rescuers walking on the grain surface which is another reason to minimize the number of rescuers on the grain surface. Cases have been reported in which large masses of spoiled or frozen grain have fallen on individuals causing injury.

2.5 Why can't the main access door in the bin, at ground level, be opened to let the grain out quickly?

The typical grain bin has a two part door system that includes an outside door that opens outward and an inside door that swings in. The outside door can be easily opened by opening the latch. The inside door cannot be opened if there is grain in the bin because of the grain against the door. Even if the door could be opened or cut, the

rapid flow of grain out of the opening could cause the bin to become unstable and collapse.

2.6 Is it safe to open the outside door of a grain bin?

Not always! If someone forgot to close the inside door before filling the bin, grain will rapidly flow out of the bin and engulf anyone near the door. Fatalities have been documented in such circumstances. If the outside door is bulging out or grain is leaking out around the edges, the area should be secured and efforts made to remove the grain from the structure.

2.7 What are the most serious hazards to first responders at the scene of a grain entrapment?

A variety of injuries have been documented to first responders involved with a grain storage rescue including: falls from bin, over exertion, allergic response to suspended mold spores and dust, over heating due to the higher temperatures that can develop inside the bin, and run over by equipment being used to remove evacuated grain from around the bin.

2.8 Should the unloading system of a grain storage structure be used to free a victim?

No. Turning on the unloading auger or opening the bottom openings will cause the victim to be drawn deeper into the grain mass. Extrication, in most cases, involves removing the grain from around the victim.

2.9 What is the safest way to cut open a storage bin to evacuate the grain in the least amount of time?

On small grain storage bins (less than 30,000 bushels), the quickest way to release the grain in order to reach a completely submerged victim is to cut openings around the base of the bin and allow the grain to spill directly on the ground. The recommended strategy is to cut “V”-shaped openings as high up on the side of the bin as possible or at the level that the victim has been located. This will result in the need for less grain to be removed. Openings should be cut uniformly around the base of the bin to allow for uniform release of the grain and reduce unequal pressures on the structure.

2.10 Is there a danger of bin/structure collapse if holes are cut in the side of the structure to release the grain during a rescue?

Yes and No. It is not recommended that holes be cut into the side of larger grain storage structures such as concrete silos, welded steel tanks or corrugated steel bins over 30,000 bushels in capacity. The structural integrity of these structures, if cut, is not well understood or documented. The safest strategy is to remove the grain with large grain vacuum units. Before cutting openings in any large structure consult with the manufacturer, or a Professional Engineer experienced with the design and characteristics of these facilities. Failure of these structures can put first responders at great risk of injury or death.

2.11 Can there be elevated carbon dioxide (CO_2) levels inside a wet holding bin?

Yes. As unconditioned corn with more than 14-16% moisture content begins to spoil it releases carbon dioxide that can accumulate above the surface of grain. Levels, in some cases, have been documented above what is considered safe without self-contained breathing apparatus (SCBA).

2.12 Why should the aeration or drier fans be turned on during a rescue?

Turning on the aeration fan during a rescue will provide an air flow to a victim that may be completely buried and contribute to better air quality inside the bin for rescuers. If the outside temperature is high, the inside temperature will be even hotter. Air movement through the bin will also help reduce the inside temperature reducing the risk of heat stress of first responders.

2.13 Why is respiratory protection needed for first responders during a grain rescue?

A common characteristic contributing to entrapments and engulfments is out of condition grain due to spoilage from molds. During a rescue billions of mold spores and organic dust particles becomes airborne and become a significant respiratory threat to anyone at the scene. A good quality dust mask, that is frequently changed, or in some cases, full self contained breathing apparatus will be needed. Post assessment of all first responders should take place to ensure that there is no evidence or symptoms of an allergic response that for some individuals may be severe.

2.14 Why is it important to limit the number of first responders who enter the scene of a victim entrapped or engulfed in grain?

No more than two first responders should be on the grain surface in which a victim is entrapped or engulfed. Additional personnel will only increase the risk of secondary entrapment and further compact the grain making rescue more difficult.

2.15 Is it possible to extricate an entrapped victim by using a harness, lifeline and lifting aid?

No. Applying the needed force to free a victim partially buried in grain will result in serious bodily injury and even death. The drag and weight of the grain on the victim's body is so great that it may take hundreds of pounds of pull to free him. The safest extrication strategy has been to remove the grain from around the victim and then lifting him free.

2.16 Why can't a partially entrapped victim be easily dug out of the grain?

First the amount of grain that needs to be removed to free a victim is substantial and would require large capacity grain handling equipment such as a gain vacuum machine. Second, the nature of grain to free flow makes it nearly impossible to keep it from flowing back onto the victim without some form of barrier such as a coffer dam.

2.17 What is a grain rescue device or tube?

Historically, it has been found that building a grain retaining wall or coffer dam around the victim and then removing the grain from within the remaining space is an effective rescue strategy. In the past, pieces of plywood, back boards, garbage cans and barrels with the bottom removed, and other items have been used successfully to protect the victim from back flowing grain.

2.18 How can the grain be removed from inside the grain retaining device or tube?

The quickest method that has been found to remove grain from inside the retaining wall or tube is a portable vacuum. If the retaining ring size is kept to a minimum, around the victim, the amount of grain that needs to be removed is relatively small, usually not more than two to four bushels. Small portable, 18-volt battery powered vacuums have been successfully used to remove the grain without the need for power cards.

2.19 Why, in some cases, does the victim become hypothermic while buried in the grain?

Grain is conditioned, to prevent spoilage, by passing dry outside air through the grain mass using large fans. As the outside temperature drops the cold air drawn into the bin can reduce the grain temperature at the core of the structure to near outside temperatures that may be in the 30's and 40's. A victim deeply buried in the cold grain can become chilled quickly leading to hyperthermia.

2.20 Would using a cutting tool such as an abrasive wheel or torch to cut open the side wall of a metal bin cause a dust explosion?

No. There have been no substantiated reports of a dust explosion caused by cutting open a metal storage bin during a rescue attempt. It is recommended however that first responders wear full protection and that a charged line be available. It should be noted that corn has a relatively high ignition temperature and that it is the grain dust in suspension that can be readily ignited.

3. Grain Entrapment Prevention Measures

3.1. What are the most effective strategies to prevent grain-related entrapments and engulfments?

First, the most important measure to prevent grain entrapments is proper grain management. Grain that is stored at the correct moisture content, 14% or less, and is protected from the elements remains in good condition and is easier to remove from the storage structure without plugging. There is a direct correlation between out-of-condition grain and the increased probability of entrapment.

Other important prevention strategies include:

- Never entering a storage structure while it is being unloaded.
- Never entering a grain storage structure without an outside observer or before letting others know (use of entry permit).
- Utilizing lockout/tag out procedures to ensure unloading equipment is not energized while someone is inside the structure.
- Clearly posting the potential for engulfment at each access point.
- Always having a radio or cell phone when working alone or when doing hazardous tasks around grain storage.

- Implementing a policy that all grain storage structures, open piles of grain, and grain transport vehicles are off limits to children, visitors, and non-essential employees.

3.2. Why are farms and feedlots exempt from the OSHA Grain Handling Standards?

There are two reasons - political and economic. When the standards were drafted by the Congress, language was incorporated to exempt farmers, feedlot owners, and other agricultural production sites to reduce opposition to the passage of the legislation. Secondly, the tremendous cost of bringing the hundreds of thousands of on-farm grain storage structures into compliance with the current requirements of the standard would fundamentally force a change in the way agricultural production is carried out and the prices of crops determined. It may not be economically possible to make the changes needed for compliance without substantial external financial investments.

3.3. Where can I get more information on effective stored grain management practices?

The first place to look is the local County Extension Office which has access to grain management resources from across the country. Manufacturers of grain storage systems are also an important resource along with neighbors who have documented their ability to successful store grain. There are also websites such as www.grainquality.org that provides helpful information.

3.4. What grain storage structure design features can contribute to reducing the probability of grain spoilage and entrapments?

- Use of stirrators to mix the grain.
- Temperature monitors to detect grain heating, a sign of spoilage and insect infestation.
- Installation of vents on roofs away from the direction of prevailing winds.
- Sound roof with overhanging eves that prevent rain and snow from blowing in.
- Weather seals on doors, hatches, and other access points.
- Maintaining a weather proof seal around the base of the bin.
- Installation of inside ladders.

- Warning decals posted at all access points.
- Cleaning the structure every time it is emptied.

3.5. How can the practice of "coring the bin" enhance grain quality and safe lives?

Coring the bin is a management practice that involves removing a load or two of grain from the structure once it has been filled to remove fines and broken corn that tends to accumulate in the center of the bin during filling. This damaged material tends to attract insects and more readily absorbs moisture leading to spoilage, crusting, and plugging the flow. By removing this material the quality of the grain is enhanced and the risk of entrapment is reduced.

3.6. Will a rope or chain hanging from the center of the storage structure provide adequate protection in the event of an entrapment?

In most cases no. The speed of entrapment is so fast that it is highly unlikely that a worker in the bin has the time or the instincts to grab a safety line. Second, the use of these devices may lead to greater risk taking on the assumption that if a problem occurs, there is always the safety line to fall back on. Finally, past incidents have documented that the draft and the down pressure on an engulfed victim is so great that the roof or bin ladder would probably fail under the load. In nearly all current on-farm storage bins there is not an adequate anchor point to support the weight of an engulfed victim.

3.7. Why are grain transport vehicles so dangerous to children?

Each year a small number of children, nearly all boys ages 10-12, are suffocated while inside a transport vehicle of some type. Most of these incidents involve gravity flow grain wagons and carts and straight grain trucks. The children are allowed to ride in these vehicles either empty or full, and are either entrapped and suffocated when they are covered by grain being loaded or unloaded. Children should be prohibited from riding on loads of grain or being transported in empty grain transport vehicles.

3.8 Where can I get more information on grain handling safety?

One of the best sources is the local County Extension Office that has access to safety resources from across the Land Grant System. There are also websites such as

www.farmsafety.org, www.grainsafety.us, and www.agriculturalsafety4youth that contain helpful information.

Other Resources

For additional information on rescue from grain engulfments and responding to other agricultural emergencies consider reviewing the following resources:

1. Responding to Agricultural Emergencies. NRAES-10, Cornell University, Ithaca, NY. 1999. Available from HOBAR Publications, (1-800-846-7027).
2. Rural Rescue and Emergency Care. American Academy of Orthopedic Surgeons, Rosemont, IL. 1993.
3. Don't Go With the Flow, National Grain and Feed Association, Washington, D.C. 1992. (www.ngfa.com)
4. www.grainquality.org (Purdue University website that includes a PowerPoint presentation on grain handling safety.)
5. www.grainsafety.us (Purdue University website that points to www.grainquality.org

References

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3. Freeman, S.A., K.W. Kelley, D.E. Maier, and W.E. Field. Entrapments in bulk agricultural materials at commercial grain facilities. Journal of Safety Research, 29(2):123-124. 1996.
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