Summary of Over 800 Grain Storage and Handling-related Entrapments and Suffocations Documented in the U.S. between 1970 and 2010

S.M. Riedel[1], W.E. Field[2]

[1] Purdue University, Department of Agricultural and Biological Engineering, (225 South University Drive, West Lafayette, IN 47907, USA sriedel@purdue.edu
[2] Purdue University, Department of Agricultural and Biological Engineering, (225 South University Drive, West Lafayette, IN 47907, USA field@purdue.edu

e-mail of corresponding author: field@purdue.edu

Summary

The number of victims (51) of grain-related entrapments and suffocations documented during 2010 was the highest on record. This trend towards an increasing frequency of these incidents is inconsistent with the decreasing frequency of almost all other forms of agricultural-related injuries and fatalities. Contributing factors include the increased storage of grain on-farms, increased commercial storage capacity, increased capacity of handling and transport equipment and the levels of out-of-condition grain due to delayed harvests and inappropriate processing and storage practices. Due to this increase in incidents, considerable attention is being given to exploring cost-effective intervention strategies to reduce the frequency and severity of these incidents.

This article provides a preliminary summary of data gathered on over 800 documented incidents involving entrapment or suffocation in U.S. grain storage and handling operations that have been entered into the Purdue Agriculture Confined Space Database (PACSD). Special emphasis is given to those incidents documented in 2010. The Purdue database has incident records dating back to 1964. Specific causative factors including: type of structure or facility, type of grain involved, condition of grain prior to the incident, activities at the time of entrapment and environmental conditions are summarized. Recommendations for engineering, regulatory and worker education measures are included along with the use of recently commercialized grain rescue tubes to rescue victims from entrapment situations.

Key words: grain storage, entrapment, confined space

Introduction

This study is based on data gathered at Purdue University over the past three decades on incidents involving flowing grain. The need for better documentation of confined spaces incidents including in and around grain storage, was recognized as one of the top research needs by the Committee on Agricultural Safety and Health Research and Extension for the North Central Region (NCR-197, 2003). One salient point the NCR report made was: “The likelihood that eventually all agricultural confined spaces will be regulated, as those in industrial workplaces are currently, further supports the need for research and extension [*i.e. education*] efforts” (NCR-197, 2003). Seven years later, events during the period of July 28th to August 4th highlighted this need for additional research, in order to better understand the issue of confined spaces in agriculture. On July 28th, 2010, four workers were “walking down” the grain in a grain facility in Mount Carroll, IL. Two of the victims (ages 14 and 19) died due to their entrapment and a third (age 20) was successfully extricated from the bin after being entrapped for approximately six hours. The fourth worker (age 15) was able to escape and alert workers outside the bin to secure grain-moving equipment. Response by the federal government was swift, with the Assistant Secretary of the Department of Labor (OSHA) issuing a letter one week after the incident, informing grain storage facility operators not only of the regulatory requirements that must be followed, but that future incidents would not be tolerated. He highlighted the recent civil fines levied on commercial grain facilities, and stated that in addition to any civil penalties that may be proposed, OSHA will “consider referring the [future] incident to the Department of Justice for criminal prosecution”

(Michaels, 2010) . This single incident led to the formation of a multi-state grain safety task force and production of a variety of educational resources. OSHA's commitment to safety in the grain industry was reiterated in February 2011, when they released a second letter to over 10,000 grain operators nationwide (Michaels, 2011).

Methods

Since 1978, Purdue University's Agricultural Safety and Health Program has been documenting grain entrapment[1] cases throughout the United States. These data have been gathered from a variety of sources including death certificates, police reports, newspaper clippings, and on-line searches using the following keywords: "death confined space agriculture"; "death grain bin"; "farm accident"; "farm injury"; "silo"; and "suffocation agriculture". Data is also cross-referenced and verified with researchers at other land grant institutions and facilities, such as the Great Plains Center for Agricultural Health (GPCAH), the University of Illinois, and Penn State University. Over 800 fatal and non-fatal grain entrapment cases have been documented and entered into a National Grain Entrapment Database, with the earliest case dating back to 1964. Prior work by Purdue researchers details how this data is collected, updated, and queried (Kingman, 1999). This article summarizes recently reported grain entrapment cases with special emphasis on those documented during 2010 with observations concerning the increasing frequency of these events[2] (Field & Riedel, 2010).

It should be noted that this summary does not reflect all grain-related entrapments, fatal or non-fatal that have occurred, due to the lack of a comprehensive reporting system and a continued reluctance on the part of some victims and employers to report partial entrapments where extrication was required but no public report was made. Based upon the calculated ratio of non-fatal to fatal incidents documented in Indiana over the past 30 years, which has had an aggressive surveillance program to identify these events, the total number of actual cases could be 20-30 percent greater nationwide.

Results and Discussion

Based upon the cases documented to date, no less than 51 grain entrapments occurred in 2010. In addition, there was at least one reported incident of a first responder who required medical treatment due to respiratory issues occurring during a rescue and recovery operation. This is the highest number of entrapments ever recorded; the previous highest number of cases occurred in 1993 when 42 were documented. The 2010 total compared to 33, 34 and 38 cases documented during 2007, 2008 and 2009 respectively.

The trend for this type of incident, unlike many other types of farm-related injuries and fatalities, continues to increase, as shown in Figure 1. From 2009 to 2010, there was an increase of 13 cases or over 34%. From the low point of 18 cases in 2001, the increase has been over 183%. Between 1994 and 2002, the five-year average decreased from a then-record of 29.2 recorded entrapments per year to 18.8 in 2002 (the lowest since 1987). Since 2002, however, the five-year average has increased steadily back to 29.2 incidents per year in 2008, 32.0 in 2009 and now 36.0 in 2010. This is a jump in the five-year average of 12.5% from 2009 to 2010, and an increase of over 91% from the low point of 18.8 in 2002.

[1] Flowing grain entrapments include both fatal engulfments and partial entrapments that required assistance in order for the victim to be extricated.

[2] A preliminary report for 2010 was released in early November 2010 when the total number of cases at that time exceeded the highest number of incidents ever recorded. A final report was released in February 2011 and summarizes all incidents documented in 2010.

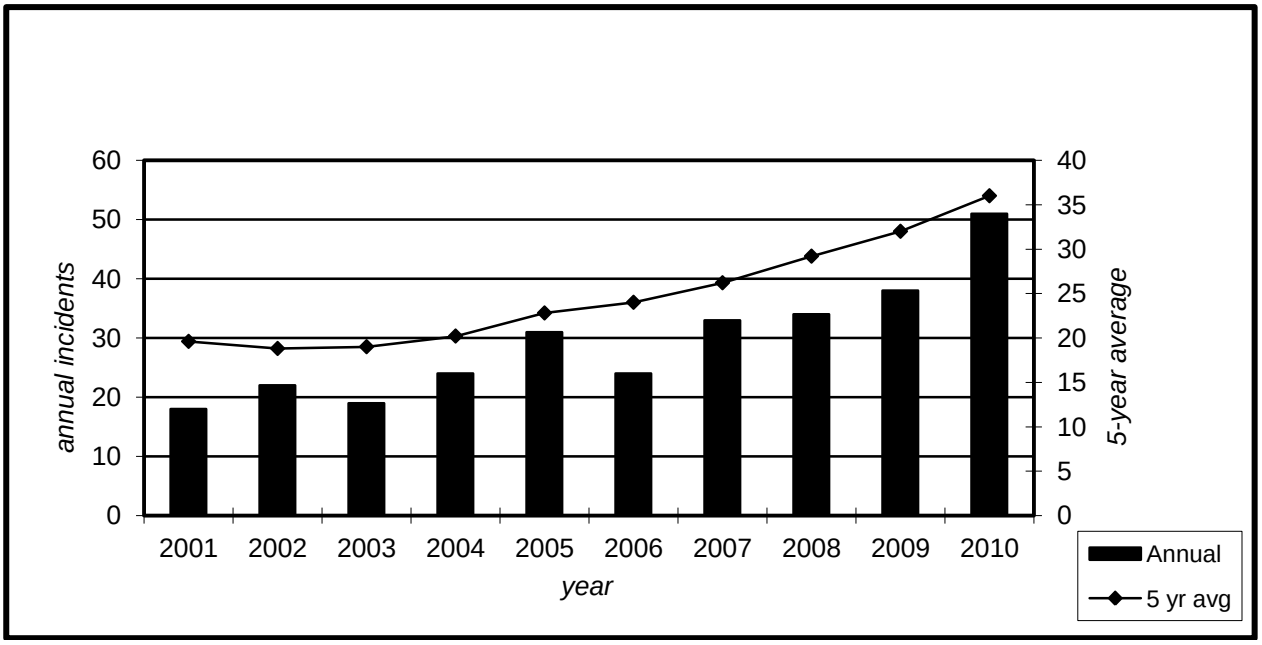

Figure 1: Number of annual grain entrapments recorded in the National Grain Entrapment Database and the 5-year average between 2001 and 2010.

In 2010, the states with the most documented grain entrapments, fatal and non-fatal, were Illinois (10), Minnesota (8), Wisconsin (7), and Iowa (5). This geographic distribution parallels the long-term trend for these events to occur primarily in the Corn Belt. Overall, entrapments were documented in 17 states in 2010.

Historically, 70% of all documented entrapments, where the site was known, have occurred on farms currently exempt from the OSHA Grain Handling Facilities standards, 29 CFR 1910.272 (OSHA, 2008) with the balance taking place at commercial grain facilities. Beginning in 2007 and 2008 this distribution of cases changed substantially with 49% of documented cases occurring on exempt farms and 51% at non-exempt commercial sites. In 2009, where the location was known, 19 (63%) entrapments occurred on farms and 11 (37%) entrapments were at commercial facilities; the classification of the location was unknown for 8 incidents. This historical trend continued in 2010, with 35 (69%) of the incidents occurring on exempt farms and 16 (31%) of the incidents occurring at commercial facilities[3]. All documented victims were male, and there continues to be a trend towards more managerial level employees / operators / owners being involved in entrapments.

In 2010 there were six incidents (12%) involving youth under the age of 16, as shown in Figure 2. All but two were at farm locations currently exempt from the OSHA Grain Handling Facilities standard. Overall, age was known for 43 of the 51 incidents in 2010, with the oldest victim being 81, and the youngest seven years old. The average age was 45 years old, and the median age 49.

[3] In the past, it was difficult to discern whether an incident occurred on an exempt farm or at a commercial facility due to incomplete reporting. In 2010, documentation allowed for a determination in each case.

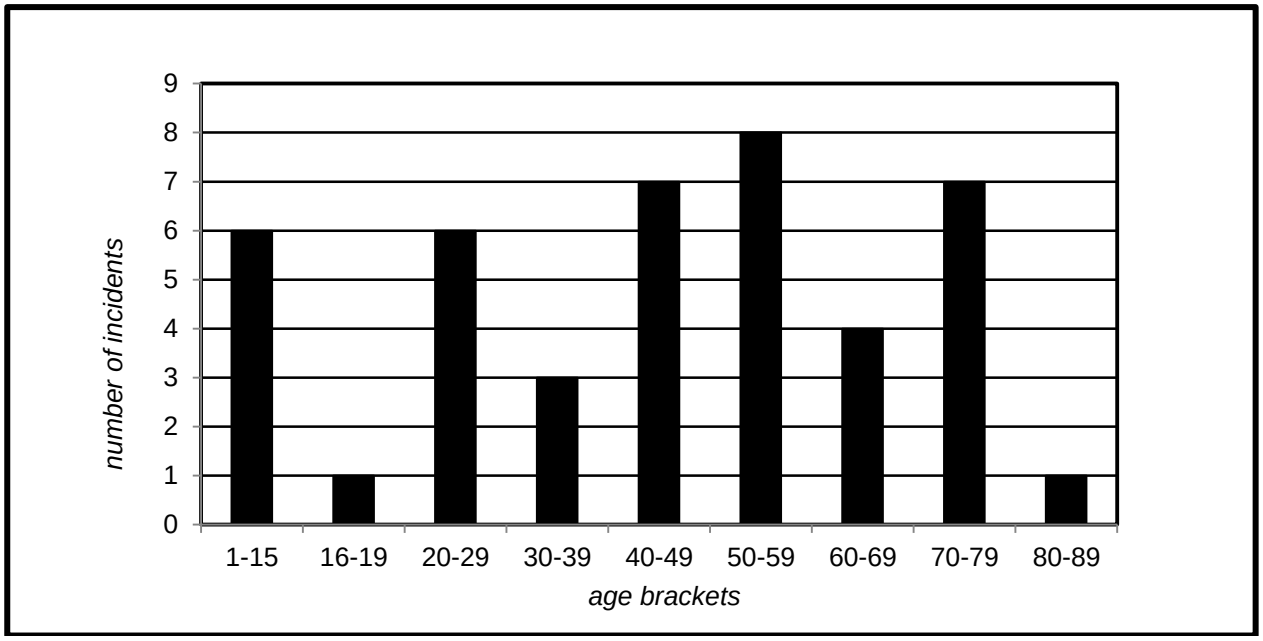

Figure 2: Age distribution of victims by number of incidents in 2010 recorded in the Purdue University Confined Spaces in Agriculture Dataase.

As shown in Figure 3, in 2008 and 2009 the ratio of fatal to non-fatal incidents decreased when compared to earlier years. From 1964-2005, 74% of documented entrapments resulted in death. During 2008, 45% of the entrapments resulted in death with 42% of the entrapments in 2009 resulting in death, and 51% of cases resulting in death in 2010. It should be noted that 5 of the 6 cases involving youth under 16 (83%) in 2010 resulted in death. Even though the reporting of child-related incidents from exempt facilities is very incomplete, the high percentage of incidents involving youth that result in fatalities should be of concern. It is possible that more victims may be surviving these incidents due to increased emphasis on safer confined space entry procedures, such as using an observer during confined space entry, as well as an increased emphasis on first responder training on grain entrapment extrication. At least two of the incidents documented in 2010 involved extrication using commercially available grain rescue tubes which were not widely available until 2007/2008.

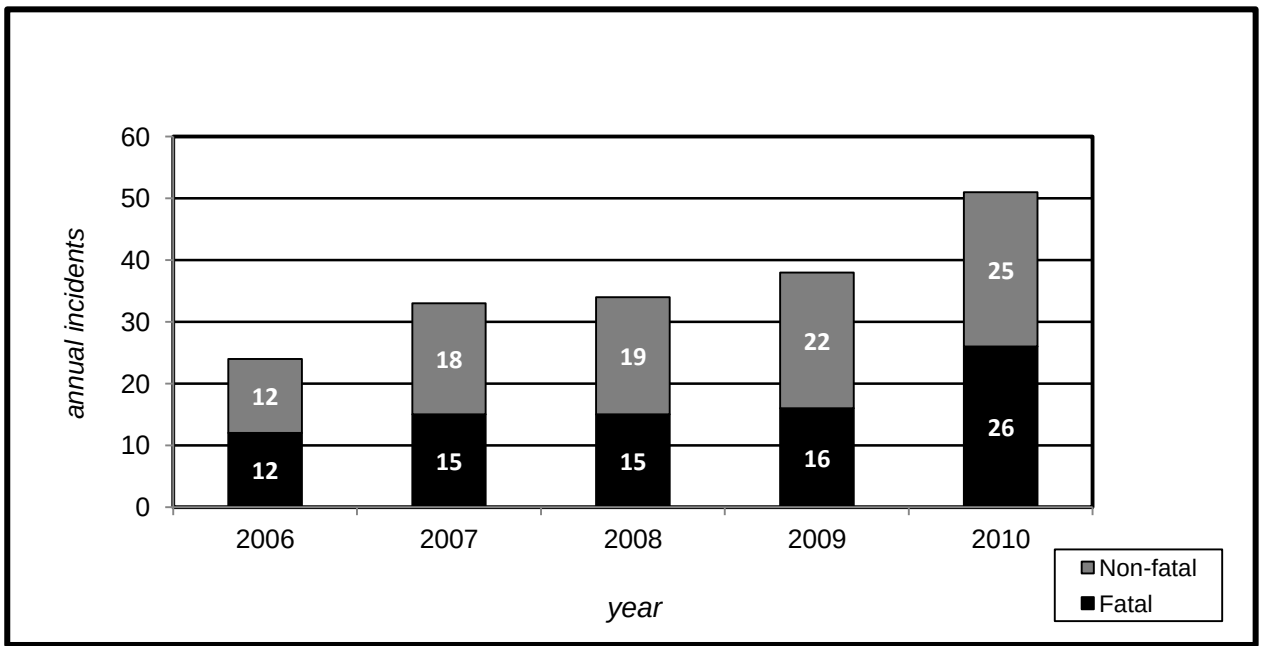

Figure 3: Fatal vs. non fatal incidents recorded in the National Grain Entrapment Database between 2006 and 2010.

During 2010, the primary medium of entrapment, when identified, remained yellow corn (37 incidents, 73%). Over the past thirty years corn has been involved in approximately 45% of the grain-related entrapments where the medium was known. If further inquiry was conducted on the unknown cases, it is believed that the portion involving corn would be higher, since corn accounts for approximately two-thirds of the typical flowing agricultural material crops (NASS, 2010). Other bulk materials that were documented in entrapments included processed feed, soybeans, sorghum, barley, sunflower seeds, and peanuts.

In 2010, the primary causes leading to entrapment were entering a bin to loosen crusted, spoiled or frozen grain while unloading equipment was running (26 incidents, 51%), or falling into grain transport vehicles while they were being either loaded or unloaded (3 incidents, 6%). There continues to be an association between out-of-condition or spoiled grain and the increased probability of entrapment.

The 2009 crop was record in size and the 2010 crop was not too far behind in the amount harvested[4]. While the harvest conditions were much better for 2010, the less than ideal conditions of 2009 resulted in more reports of out-of-condition or spoiled grain in storage and increased incidents of plugged flow. This was primarily due to the high moisture levels farmers and commercial grain facilities were allowing to occur in stored grain. In addition, the domestic corn demand for ethanol has resulted in the largest build up of storage capacity across the Midwestern U.S. in history. These factors have resulted in more corn being stored for longer periods of time than in past years and possibly an increased potential for grains to go out of condition leading to another increase in grain entrapments unless there is a change in current work practices.

Entrapment Rescue Strategies

Approximately half of all documented entrapments have historically resulted in a fatality with the balance requiring assistance in extrication from the grain mass. Over the years a variety of strategies have been used to remove the entrapped victim including the use of grain retainment structures fabricated onsite and releasing the grain from the structure by cutting holes in the walls. Early attempts to commercialize grain rescue devices or to have them widely adopted were unsuccessful until 2007-2009 when at least three different designs of commercial grain rescue tubes became available. All of these units allow for a cylinder to be inserted into the grain around the victim therby reducing the pressure on the victim and allowing for the grain immediately around the victim to be removed allowing for rescue. These devices have been used in at least three documented cases to successfully remove an entrapped victim from grain. It is anticipated that future incidents will report greater utilization of grain rescue equipment. Research on prior entrapments documented in the Purdue database has explored the use of both locally fabricated grain retainment systems and commercial grain rescue tubes (Roberts, 2008).

Recommendations

There exists a continuing need for an industry wide consensus on the importance of developing engineering safety design and practice standards for grain storage structures. The commercial grain industry and grain bin manufacturers are urged to increase their employee, farmer, and customer education efforts to prevent grain entrapments from occurring. In addition, there is the need to strengthen employee and emergency responder training to ensure having in place appropriate response strategies in case of grain entrapments. While each incident is unique in the challenges it poses to first responders, research shows that use of grain retaining devices such as rescue tubes, grain retaining walls, or cofferdams, along with grain removal strategies, increases the likelihood of successful rescue of a partially entrapped victim (Roberts, 2008). Commercially fabricated grain resue tubes have been readily available since the 2007/2008 time-frame; training in the use of these devices for grain facility employees and first responders should be a significant portion of the response strategy for entrapments.

[4] According to USDA, National Agricultural Statistics Service crop production data for 2009 and 2010, corn harvested in 2009 amounted to 13.11 billion bushels and soybeans harvested were 3.36 billion bushels. In 2010, corn harvested amounted to 12.45 billion bushels and soybeans harvested were 3.33 billion bushels.

Training resources such as the videos “Don’t Go with the Flow” and “Your Safety Matters” are available from the National Grain & Feed Association (www.ngfa.org), which were developed in response to the observed upswing in grain entrapment incidents at commercial fatalities during the early 1990s. Farmer / agricultural producer oriented safety resources are also available from www.grainquality.org, National Corn Growers Association (www.ncga.com), from local Extension offices, or from www.grainsafety.us.

Every flowing grain entrapment is a preventable incident. The recent record crops from 2009 and 2010 should be a reason to celebrate and not the cause for tragedy and sorrow. The grain entrapment problem can be addressed through the use of appropriately designed storage facilities, proper grain storage practices, proper use of personal protective equipment, implementation of safe work practices and having in place effective emergency response capabilities.

References

Field, W., & Riedel, S. (2011). *2010 Summary of Grain Entrapments in the United States.* Purdue University, Agricultural and Biological Engineering. West Lafayette: Purdue University.

Kingman, D. M. (1999). *Prevention Strategies for Flowing Grain Entrapments in On-Farm Grain Storage Bins.* Purdue University, Agricultural and Biological Engineering. West Lafayette: Purdue University.

Michaels, D. (2010, August 4). *OSHA.* Retrieved August 5, 2010, from US Department of Labor: http://www.osha.gov/asst-sec/Grain_letter.html

Michaels, D. (2011, February 1). *OSHA.* Retrieved March 4, 2011, from US Department of Labor: http://www.osha.gov/asst-sec/Grain-Letter-2-1-2011.html

NASS. (2010). *Crop Production (December 2010).* US Department of Agriculture, National Agricultural Statistics Service. Washington: US Department od Agriculture.

NCR-197. (2003). *National Land Grant Research and Extension Agenda for Agricultural Safety and Health.* US Department of Agriculture. Washington, DC: Cooperative Extension.

OSHA. (2008). *Grain Handling Facilities (29 CFR 1910.272).* Washington, D.C.: Department of Labor.

Roberts, M. J. (2008). *Summary of Prior Grain Entrapment Rescue Strategies and Application Principles Associated with Using a Grain Rescue Tube as a Grain Retaining Device.* Purdue University, Agricultural and Biological Engineering. West Lafayette: Purdue University.