2023 Summary of U.S. Agricultural Confined Space-related Injuries and Fatalities

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Highlights

The following are highlights from the 2023 findings:

- No fewer than 55 cases involving agricultural confined spaces were documented, including 29 fatal and 26 non-fatal cases[1], representing a 33.7% decrease over the 83 cases in 2022
- There were no fewer than 27 grain related entrapments in 2023 representing a 35.7% decrease over 2022, with the balance of 28 involving livestock waste handling facilities, entanglements and grain dust explosions or fires
- Three incidents involved more than one victim
- Two cases involved livestock waste storage pits or lagoons, both of which were fatal
- Nine grain dust explosions at commercial facilities resulted in 12 non-fatal injuries[2]
- Two female cases were documented in 2023, one of which involved a dairy farm manure pit explosion and the other a fall from a grain elevator
- 53% (29) of 2023 cases were fatal compared to 59% historically
- Illinois reported the most total confined space-related cases in 2023 (12), followed by Iowa (5), while Minnesota, Missouri, Nebraska, Pennsylvania and Wisconsin had 4 cases each
- Iowa reported the most grain-entrapment cases in 2023 (5). Iowa, Indiana, Minnesota, Illinois and Nebraska, in that order, have historically recorded the most grain entrapment cases

[1] A case refers to one individual. Some incidents involve multiple victims or cases.
[2] Grain dust explosion related cases are included in the data being reported in this summary.

- A summary of vertical forage silo incidents documented four fatalities and three non-fatal cases
- OSHA Regions 5 and 7 have historically accounted for 67.9% of all documented agricultural confined space-related incidents

Introduction

Since the 1970's, Purdue University's Agricultural and Biological Engineering Department has been documenting and investigating incidents involving grain storage and handling facilities at both commercial and on-farm locations. Beginning in 2013, the effort was expanded with support from a U.S. Department of Labor Susan Harwood Training Grant, to include incidents involving grain transport vehicles (trucks, wagons, railcars); injuries occurring inside of confined spaces due to exposure to powered mechanical components, such as augers; falls from or into confined spaces; and other types of agricultural confined spaces including forage storage silos, liquid storage tanks, manure storage facilities and transport vehicles. Data has been coded and stored in the Purdue Agricultural Confined Space Incident Database (PACSID).

To learn more about the process of identifying, documenting, and coding the data for this report, please refer to the 2022 summary available at www.agconfinedspaces.org. The methodology employed has remained consistent for multiple years.

As of the end of 2023, the PACSID contained information on 2,378 cases, documented between 1962 and 2023,[3] that resulted in an injury, fatality, or required emergency extrication by first responders. In the database, 58.7% of documented cases were reported as grain entrapments, making it the leading cause of agricultural confined space-related incidents. Approximately 58% of all documented cases have historically resulted in fatality.

The total number of cases in previous summaries may differ as new cases are identified. Also, earlier years of surveillance focused only on grain storage and handling-related confined spaces, while later years include incidents such as falls, entanglements, asphyxiations, and drownings in manure storage facilities and other agricultural confined spaces.

As noted in previous summaries[4], there is no claim that the data presented accounts for all incidents involving agricultural confined spaces. The early focus on grain-related incidents has resulted in the disproportionate number of these cases included in the database. Furthermore, there is no accurate accumulative public record of these incidents due to the fact that there is no

[3] There is one case in the database that occurred in 1956.
[4] See www.agconfinedspaces.org for earlier summaries.

comprehensive or mandatory incident/injury reporting systems for most of agriculture. In addition, there has been reluctance on the part of some victims and employers to report "near-misses" or non-fatal confined space-related incidents, especially those occurring at farms, feedlots and seed processing operations not covered by federal OSHA injury reporting requirements. Based upon earlier research, it is estimated that approximately 30% of cases go unreported or undocumented (Riedel and Field, 2013).

This report summarizes cases documented in 2023 and provides an updated historical perspective, including trends. Specific attention is given to cases involving grain storage and handling facilities (which accounted for most cases), and manure storage and handling operations, the second largest category of incidents. The report also provides a brief overview of the fires and explosions that have occurred at grain storage and handling facilities; discusses the adequacy of safety training for workers and emergency first responders; highlights the growing size of financial settlements resulting from civil litigation associated with these occurrences; and includes a first-time summary of incidents involving vertical, or tower silos used to store silage and other forages.

The reasons for annually releasing these summaries have stayed unchanged, with the aim of contributing to the decrease in the frequency and severity of such incidents by keeping the public focused on the issue, aiding in the documentation of more effective, evidence-based, prevention and injury reduction methods, and giving direction to policymakers and engineering organizations in developing improved safety and health workplace regulations and design standards for future construction of related facilities.

2023 Summary of All Documented Agricultural-Confined Space-Related Cases

In 2023, there were a total of 55 cases documented, including 27 grain entrapments, 4 falls into or from grain storage structures, 5 asphyxiations due to deficient oxygen levels or toxic environments, 6 equipment entanglements (such as those involving in-floor and sweep augers) that occurred while working inside or around agricultural confined spaces, and 9 cases involving grain handling facility fires or explosions (Figure 1). The total of 55 incidents represents a 33.7% decrease from the 83 cases documented in 2022. The number of 2023 cases was also less than both the 5-year average (65.6 cases/year), and the 10-year average (62.6 cases/year) (Figure 2). Despite the significant resources being devoted to addressing the issue, the frequency and

severity of reported cases continues to be a cause for concern. As previously mentioned, the factor that contributed the most to the earlier rise in the yearly frequency can be linked to better documentation of incidents due to more extensive surveillance initiatives, increased availability of case details via the internet, and the inclusion of a wider range of data on confined space-related incidents, including those related to the storage of livestock waste and enclosed transport vehicles.

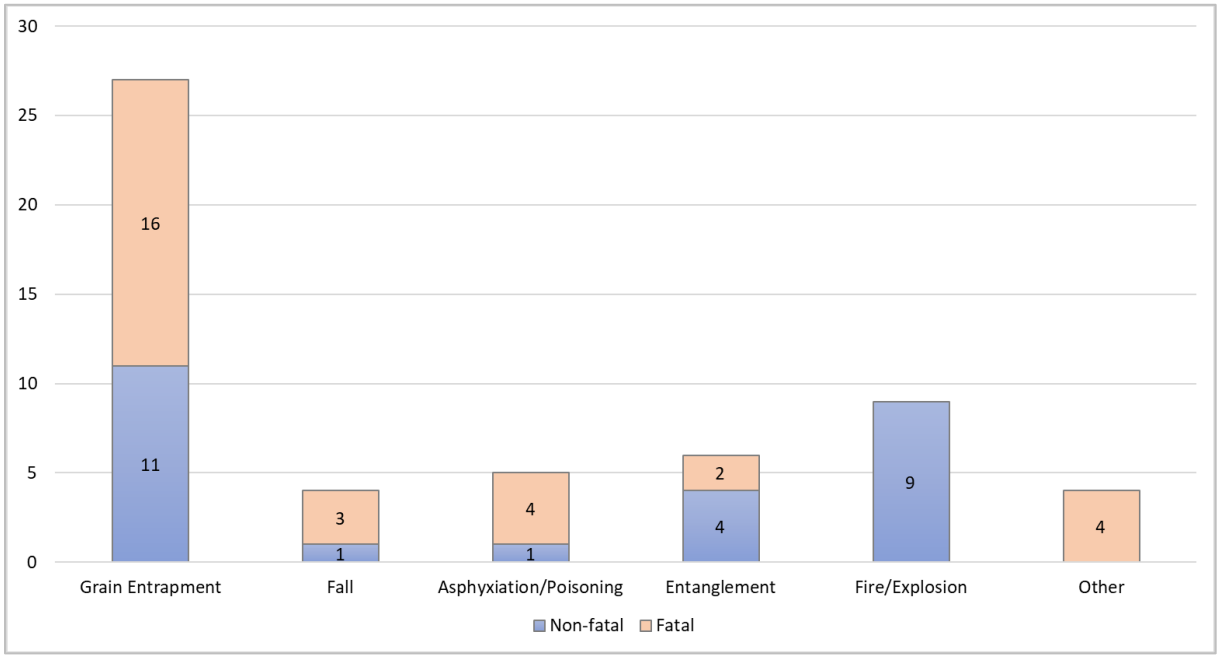

Figure 1. Distribution of all 2023 agricultural confined space-related cases by type of incident, n=55

During 2023, grain entrapments accounted for 27 (49%) of all documented cases and there were more non-fatal cases documented than fatal (Figure 2). Historically, however, there have been considerably more documented fatal cases than non-fatal cases, further suggesting under-reporting of non-fatal incidents (Another factor maybe the increased level of training taking place for emergency first responders on more effective rescue strategies). However there is no reliable research that confirms a relationship between first responder training and reduced frequency of fatal incidents.

The 5-year average for non-fatal cases was 36.2 cases/year and 29.4 annually for fatal cases. In 2023, the number of fatal cases (29) was slightly below the 5-year average of 29.4. However, the frequency of these incidents, despite stabilizing over the past six years, shows minimal significant improvement from current prevention efforts.

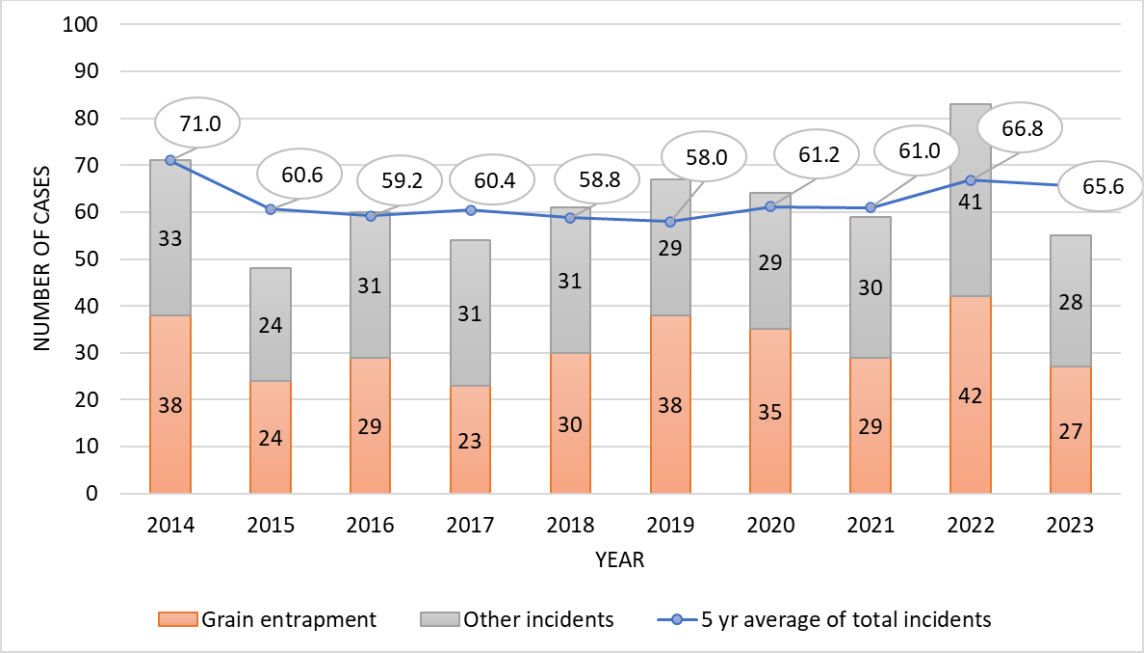

Figure 2. Comparison of the number of grain entrapment cases versus all other confined space cases recorded between 2014 to 2023

During 2023, incidents were documented in 20 states. Figure 3 illustrates the geographic distribution of all documented cases in the PACSID and those documented in 2023. The states with the most documented confined space cases of all types in 2023, including fatal and non-fatal, were Illinois (12), Iowa (5), Minnesota (4), Wisconsin (4), Nebraska (4) and Pennsylvania (4). The geographic distribution does not include cases where the state was unidentified because the site of the incident may have varied from the state where the victim died due to medical transport. The four states with the largest number of cases, historically, have been Iowa (293), Indiana (240), Illinois (230), and Minnesota (229). As noted in previous summaries, there is an estimation that the surveillance effort currently in place could potentially underreport cases, especially non-fatal, by up to 30%, mainly due to inadequate reporting mechanisms. Additionally, it is believed that Indiana has achieved a high ranking in this regard as a result of more proactive surveillance measures implemented over the past four decades.

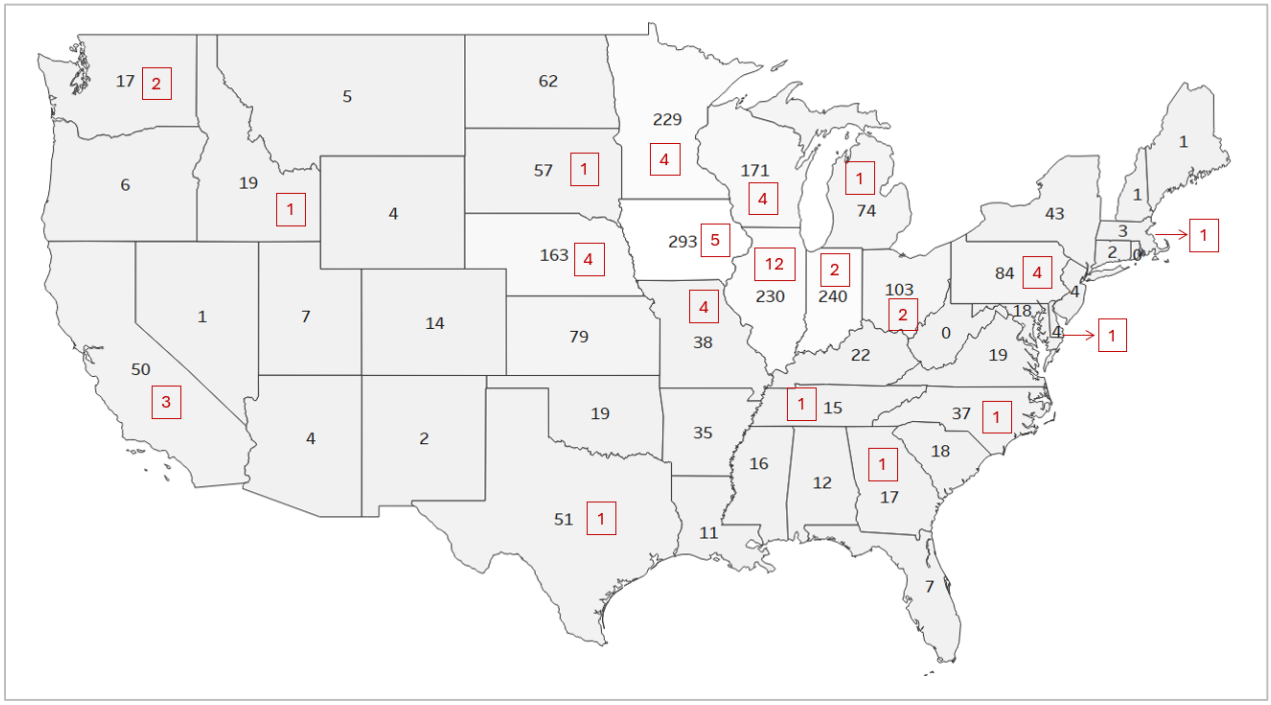

Figure 3. Geographic distribution of documented agricultural confined space cases for 2023 and previous years when site could be determined (n=2378)

In 2023, no cases involved children or youth under the age of 21, as shown in Figure 4. A specific age was known for 28 of the 55 victims in 2023, with the oldest victim being 81 and the youngest 21 years old. Those over the age of 60 accounted for 8 (28.6%) of the cases where age was known, reflecting the increasing average age of farmers (57.5 years old) in the U.S. As noted, 27 of the cases were documented without the specific age of the victim. Based upon a review of the case reports, it was concluded that in nearly all cases the victims, in which an age could not be ascertained were adults due to the lack of identifiers such as “child” or “youth”. There were two female cases documented in 2023, which involved in an explosion and a fall.

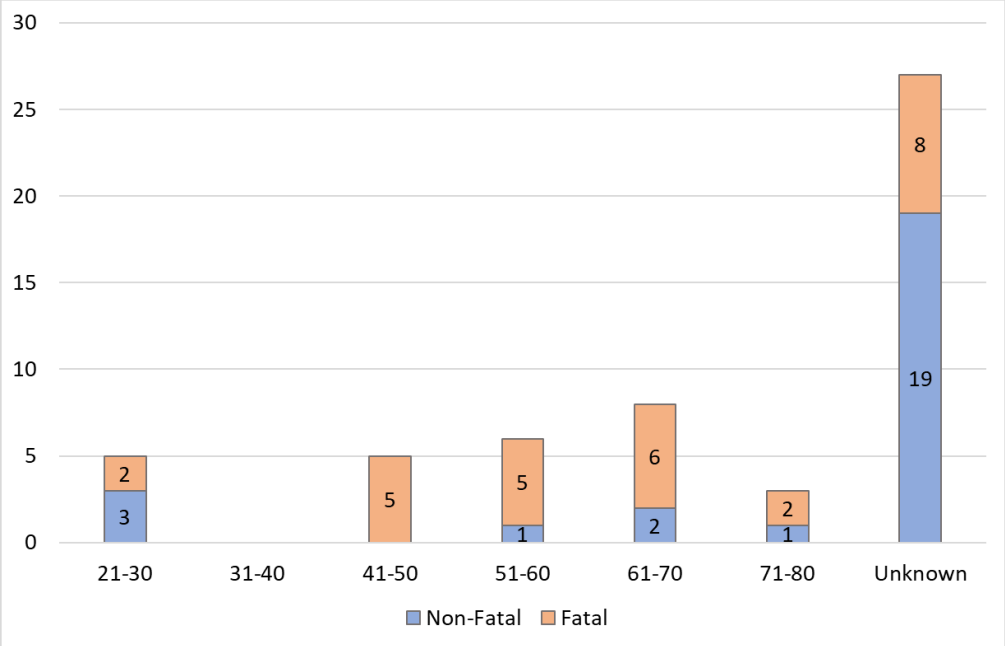

Figure 4. Age distribution of all 2023 agricultural confined space incident victims

In 2023, there were 36 cases where the exemption status[5] of the facility with respect to OSHA regulations was known. Half (18) of these cases occurred on farms or other locations currently exempt from enforcement under the OSHA Grain Handling Facilities Standards (29 CFR 1910.272) or Confined Space Standards (29 CFR 1910.146). The balance of known cases, 18 (50%) took place at non-exempt commercial grain facilities. Based on historical data, it is believed that most of the cases where OSHA status could not be determined have been OSHA exempt.

Analysis on the Distribution of Incident Type and Facility by US and OSHA Regions.

A total of 2,378 cases have been identified by OSHA region. Agricultural confined space-related cases have occurred in every OSHA region but tend to be concentrated in two regions, regions 5 and 7 (Figure 5). Historically, Region 5 has accounted for 43.8% of all agricultural confined space cases (1,042) nationally, with 57.9% of those cases being grain entrapments, and 12.4% being falls. Region 7 accounted for 573 cases (24.1% of the U.S. total) with grain entrapments, asphyxiation and entanglements representing 83.6% of those cases. Region 1

[5] Under the current provisions of the two OSHA workplace safety and health standards most relevant to agricultural confined spaces, agricultural worksites, including most farms, feedlots, and certain seed processing operations are exempt from compliance with confined space entry provisions and reporting requirements.

represented the region with the smallest number of grain entrapments while region 6 represented the region with the highest percentage of total documented cases being grain entrapment cases (70.3%).

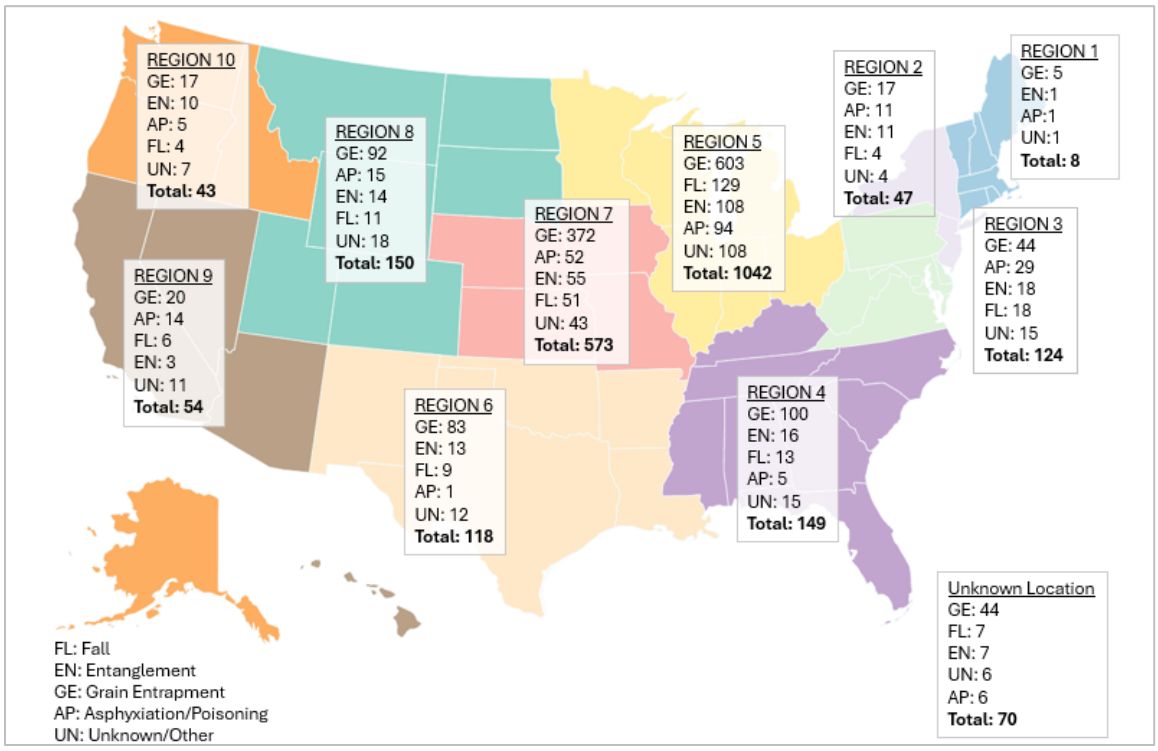

Figure 5. Agricultural confined case distribution by OSHA region from 1962-2023. The total number of cases and most frequent type of case is listed for each region (n=2378)

Grain Entrapments

The 27 fatal and non-fatal grain entrapment cases[6] documented in 2023 represented a 35.7% decrease from the 42 recorded in 2022 and was slightly lower than the 5-year average of 34.2 cases/year (Figure 6). As noted in the 2022 summary, the total fatalities, and the non-fatal grain entrapment cases, in that year (42) were both the highest in the past decade. Nevertheless, the 5-year running average continues to drop from its peak of 40.4 in 2011. Of the reported entrapment cases in 2023, 59.3% resulted in a fatality, which is higher than the five-year average which places doubt over the actual impact of grain rescue training on increasing the survival rate. The state with the most documented grain entrapments (fatal and non-fatal), was Iowa with five, followed by Nebraska with four, and Missouri with three cases. The majority of grain entrapment cases occurred in the Midwest, or Corn Belt (64.3%). Historically, 74% of previously

[6] These cases include only those cases involving entrapment or engulfment in flowing grain. They do not include fatal or non-fatal cases involving falls from grain storage structures or entanglement in grain handling equipment such as in floor or sweep augers.

documented cases have occurred in the Corn Belt region. Figure 7 provides a geographic distribution of all documented grain entrapment cases contained in the PACSID for which the incident location was known. Iowa was the site for the highest cumulative number of documented grain entrapment cases (187) with Indiana a close second (179). Considering the total grain production and grain storage capacity, Illinois, Minnesota and Nebraska, ought to have a significantly greater number of cases than reported in Indiana.

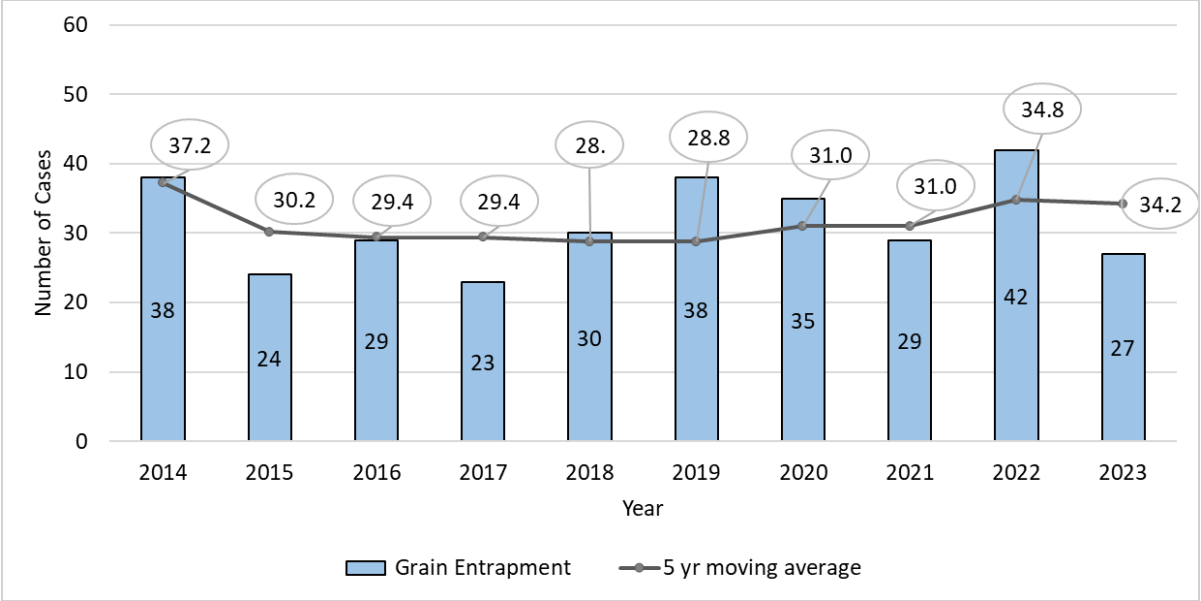

Figure 6. Number of annual grain entrapment cases recorded between 2014 and 2023

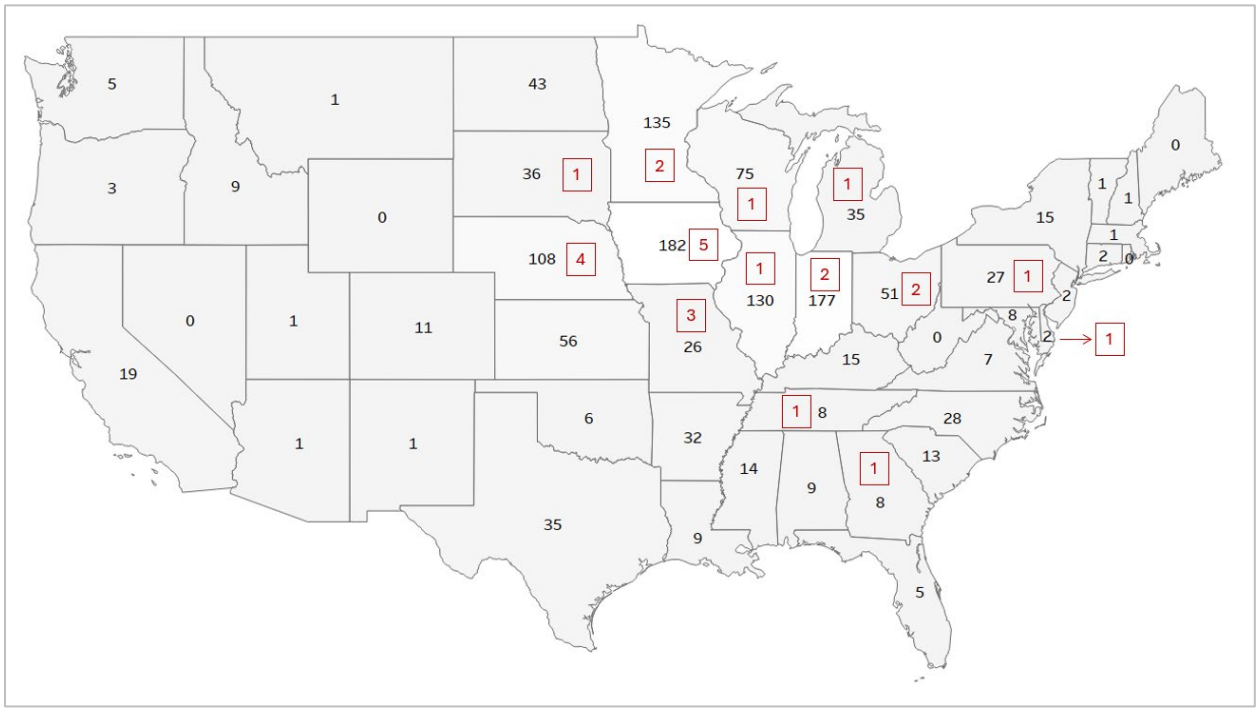

Figure 7. Geographic distribution of grain entrapment cases in 2023 and previous years (N=1396)

All documented grain entrapment cases in 2023 involved males. The oldest victim of grain entrapment was 81 (figure 8). The average age was 56.4 years old and the median age was 60. In over 40.7% of the cases, the specific age could not be documented, however review of the reports strongly indicates that nearly all were adults.

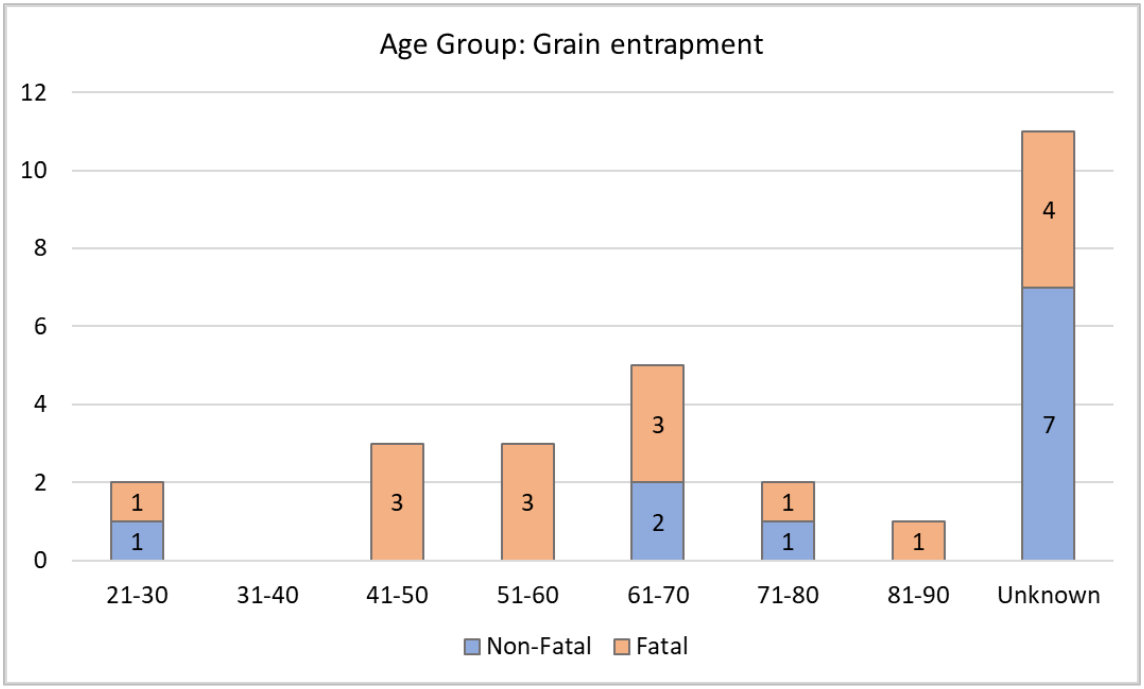

Figure 8. Age distribution of 2023 grain entrapment victims by number of cases recorded (N=27)

Again, as previously stated, over two-thirds of U.S. grain storage capacity is on farms which are exempt from OSHA injury reporting requirements. It is highly likely that this summary does not encompass all grain-related entrapments, whether resulting in death or not.

2023 Summary of Grain Dust Related Explosions

In 2023, there were a total of 9 grain dust explosions documented. Three of those incidents resulted in non-fatal injuries, with one Illinois explosion accounting for 8 injuries. No fatalities due to grain dust explosions were documented in 2023. The ten-year average for injuries is 9.5 and 1.2 for fatalities. The explosions occurred at 1 ethanol plant, 1 wheat mill, 2 grain elevators, 2 soybean processing facilities, 2 corn processing facilities, and 1 corn cob processing plant. Dust explosions occurred in 4 different states: 3 each in Illinois and Minnesota, 2 in Iowa, and 1 in Indiana.

Summary of 2023 Agricultural Waste Storage, Handling, Transport Equipment and Facility-related Incidents

Nour et al. (2021) summarized findings of livestock waste-related, confined space, incidents from 1975 to 2021. He analyzed 409 incidents involving 486 individuals, of which 595 were fatal. The study revealed that the majority of victims (85%) were male, with an average age of 37, highlighting a higher risk for youth in agricultural waste-related incidents as compared to grain storage. The most common incidents implicated various manure storage facilities and transport vehicles, with around 11% involving multiple victims. In 2020, there were 11 injuries and fatalities related to livestock waste, with 45% being fatal. In 2021, this increased to 13 incidents involving 16 individuals, with 75% resulting in fatalities, representing a doubling from 2020.

In 2022, there were 11 reported incidents involving 11 individuals, with 8 resulting in fatalities. All victims were male, ranging from age 16 to 74. Wisconsin and California had the highest incident counts, with three and two cases respectively. Additionally, there were non-fatal incidents involving 8 individuals injured by livestock waste transport vehicles. The primary cause of injuries or fatalities prior to 2022 was identified as performing maintenance tasks in or around manure storage structures, such as pump repair or services. This activity has consistently been the most frequently associated with cases documented since 1975.

In 2023, only two incidents were reported, each involving one individual, and both resulted in fatalities Furthermore, there were five incidents of fatal and non-fatal roadway incidents where four individuals sustained injuries caused by livestock waste transport vehicles and three individuals were killed by manure spreaders in three different incidents.

Summary of Vertical/Tower Silo-related Incidents

As part of Purdue University's on-going surveillance of agricultural confined space related incidents, cases involving vertical/ tower silos have been identified. To better understand the safety and health issues related to these structures, data regarding documented cases are being compiled separately as a new initiative. Findings will be used to enhance the quality of current agricultural safety and health educational resources.

Historically these structures have played a significant role in the expansion of livestock-based agriculture with an estimated 500,000 units in use on farms during their peak. These facilities consist of primarily older wooden stave silos, concrete stave silos, poured concrete

silos, and oxygen limited structures fabricated from glass coated steel. Units are designed to be filled with an external silage blower with contents removed via top or bottom unloading systems. Currently, vertical/ tower silos are rapidly being replaced by either bunker silos, open piles of covered silage, or silage bagging operations. Many current silo structures have outlived their anticipated life expectancy and have been abandoned.

Utilizing documented cases in the PACSID and a preliminary review of online sources, no fewer than 104 incidents involving 127 individuals (cases) were documented. Of these cases, 75 % were fatal which reflected a higher proportion of fatalities than incidents involving grain storage bins. Males accounted for 92% of the cases. When the age of all victims could be ascertained, the average age of all victims was 37. The most common incident types involved exposure to toxic gases, with "silo gas", "nitrogen dioxide", or "nitrous oxide" identified most frequently in 32% of cases. The next largest category, 23% involved falls from silos. Entanglement in silo loading or unloading equipment were associated with 17% of cases. Initially unexpected was the 9 incidents involving 6 fatalities that were caused by collapsing silo structures. States with the most frequently reported incidents were Wisconsin, Pennsylvania, Minnesota, and New York, reflecting the close association of these structures with the dairy industry.

In 2023, seven incidents involving vertical/ tower silos were documented with four resulting in fatalities. The average age of the victims was 44 when age could be determined. All known victims were male. Exposure to "silo gas" leading to asphyxiation resulted in one fatality, two cases were caused by falls, two cases involved entanglement in loading and unloading equipment, and one fatal case involved a falling object within the silo.

This is the first attempt to estimate the frequency and severity of silo-related incidents and surveillance will continue to be expanded as resources allow. Information on silo-related injuries and fatalities would be appreciated.

Are We Conducting the Right Emergency Response Training?

Ongoing surveillance of the media for incidents involving agricultural confined spaces has identified a high frequency of articles reporting on training taking place for local emergency first responders to address flowing grain rescue. These training events are occurring across the U.S., even in areas where the probability of a grain-related entrapment is extremely low, or historically non-existent. The primary focus of the training, as reported by the media, has been to address

strategies to rescue victims from partial entrapment utilizing a grain rescue tube or cofferdam. In many cases, the training appears to be a response to a local incident, which may have been the only such incident ever documented in the service area. Millions of dollars have been spent on these trainings and acquisition of specialized equipment, even in light of the fact that only about 30-35 such incidents occur annually in the entire U.S.

From a public policy perspective, the following questions should be asked: (a) Is the current level of training activities actually justified? (b) Who are the most appropriate first responders to receive the training? (c) What should the learning outcomes be for agricultural-confined space rescue training? and (d) How much specialized rescue equipment is actually needed and where should it be located for rapid deployment?

Considering the increase in the number of incidents involving livestock waste-related facilities, increased documentation of multiple, or secondary victims, and the growth in the number of confined spaces found on agricultural operations, it would seem appropriate that training being offered on the hazards associated with extricating victims from related confined spaces should be more comprehensive, and in alignment with actual incident data. The review of current online sources found little attention being given to this gap in training. Another gap identified in current training resources being utilized is the primary emphasis being placed on the entrapped victim with little attention being given to the potential risks to first responders of becoming secondary victims at the scene. It appears that greater attention needs to be giving to first responder safety.

The need for consistent evidence-based first responder training strategies for rescues from all types of agricultural confined spaces appears to be justified.

The Cost of Agricultural Confined Space-Related Incidents is Increasing

In the past, the economic consequences related to fatalities or injuries occurring in agricultural confined spaces were relatively minor and usually taken care of by the affected family, farm or agribusiness, insurance policies with modest coverage, Worker Compensation Insurance, or through support from the local community. With the implementation and greater enforcement of OSHA workplace safety and health regulations, non-exempt employers became exposed to the risk of financial penalties for failure to provide a safe workplace. Employers also have become increasingly aware of the financial compensation being granted through civil

litigation in cases involving injuries or fatalities in agricultural confined spaces, especially at commercial, non-exempt facilities. Juries have sent a clear message that ignoring the well-being of employees will be very expensive. In recent fatal incidents involving grain bins and livestock waste facilities, the OSHA fines have been relatively insignificant ($50-100,000), compared to the $10-17 million legal settlements that have been documented. Even for a large business, these costs are difficult to overlook.

Project Website

With support from a Susan Harwood Grant from the U.S. Department of Labor, the website (www.agconfinedspaces.org) was developed to provide resources for those conducting safety and health training in the area of agricultural confined spaces, with an emphasis on grain storage and handling hazards. Training material, frequently asked questions, past summaries of injuries and fatalities, and an extensive list of resources can be found at the site. Since 2019 it has hosted nearly 30,000 visitors.

One of the most frequently visited resources on the website is the curriculum developed for young and beginning workers in the grain industry (**Against the Grain**). The goal of this teaching resource is to provide agricultural and safety educators with an evidence-based 3-5 hour program to present basic safety and health awareness training to youth, ages 16-21, and new employees who are employed at grain handling and storage facilities, including both exempt and non-exempt operations. The curriculum has been delivered to over 5,100 youth in secondary school agricultural education programs, informal out-of-school settings, and college level agriculture classrooms. Pre- and post-testing have demonstrated a significant knowledge gain and instructor feedback has been very positive. The complete curriculum is available as a free download.

Another educational resource at the site is designed for use in training emergency first responders to safely and effectively respond to incidents at grain storage and handling facilities. Over the past nine years over 5,425 emergency first responders have participated in training using this first responder material. The curriculum is also available as a free download.

Also, check out the **Gearing Up for Safety** training material at www.agsafety4youth.info which includes two educational lessons on agricultural confined spaces.

Educational Resource

In 2018, Purdue's Agricultural Safety and Health Program collaborated with the Posey County Farm Bureau to produce STOP – THINK – LIVE, a video that re-enacts the actual grain bin entrapment of a Posey County, Indiana farmer. Copies were distributed to over 500 County Farm Bureau presidents, secondary agriculture education teachers, County Extension offices and many first responder agencies. The video includes interviews with the farmer, shows the rescue strategies used, and has short outtakes on the role of out-of-condition grain and the risk of entrapment in grain transport vehicles. The video can be viewed at www.agconfinedspaces.org or copies can be ordered for $10.00 from:

Posey County Farm Bureau
PO Box 189
30 West Main Street,
Poseyville, IN 47633-0189

Reporting An Incident

If you become aware of an incident involving an agricultural confined space, the team at Purdue would appreciate hearing from you. Incidents can be reported online at www.agconfinedspaces.org Your input would be greatly valued.

Published Works

As the result of the analysis of data gathered over the past eight years, the following articles have been published. Full text for some of these articles are available at www.agconfinedspaces.org.

Roberts, M. J. Field, W. E., Maier, D. E., Stroshine, R. L. Determination of Effort Required to Insert a Rescue Tube into Various Grain Types. ***Journal of Agricultural Safety and Health,*** 18:4, 2012.

Riedel, S. M., Field, W. E. Summation of the Frequency, Severity, and Primary Causative Factors Associated with Injuries and Fatalities Involving Confined Spaces in Agriculture. ***Journal of Agricultural Safety and Health****, 19*(2), 83-100, 2013.

Field, W. E., Heber, D. J., Riedel, S. M., Wettschurack, S. W., Roberts, M. J., Grafft, L. J. Worker Hazards Associated with the Use of Grain Vacuum Systems. ***Journal of Agricultural Safety and Health,*** 20(3), 147-163, 2014.

Issa, S.F., Field, W.E., Hamm, K.E., Cheng, Y.H., Roberts, M.J., and Riedel, S.M. Summarization of Injury and Fatality Factors Involving Youth and Grain Entrapment or Engulfment in Agriculture. ***Journal of Agricultural Safety and Health***, 22(1), 13-32, 2016 .

Roberts, M. J. Field, W. E., Maier, D. E., Stroshine, R. L. Determination of Entrapment Victim Extrication Force with and without Use of a Grain Rescue Tube. ***Journal of Agricultural Safety and Health,*** 21:2, 2015.

Issa, S.F., Cheng, Y.H., and Field, W.E. Summary of Agricultural Confined Space-related Cases: 1964-2013. ***Journal of Agricultural Safety and Health***, 22(1), 34-45, 2016.

Cheng, Y.H. and W.E. Field. Summary of Auger-related Entanglements Occurring Inside Agricultural Confined Spaces. ***Journal of Agricultural Safety and Health***, 22:2, 2016.

Issa, S.F., Field, W.E, Schwab, C.V., Issa, F.S., Nauman, E. Contributing Causes of Injury or Death in Grain Entrapment, Engulfment and Extrication. ***Journal of Agromedicine***, 22:2, 2017.

Issa, S.F. and Field, W.E. Determining the Pull-Forces Required to Extricate a Victim Entrapped at Various Angles in a Grain Mass. ***Safety***, Accepted for publication, 2017.

Cheng, Y.H., Field, W.E., Tormoehlen, R.L., French, B. Utilizing Secondary Agricultural Education Programs to Deliver a Grain safety Training for Young and Beginner Workers. ***Journal of Agromedicine,*** 22:4, 2017.

Field, W.E., Cheng, Y.H., Tormoehlen, R.L., Aherin, R., Schwab, C., Neenan, D., Roberts, M. Let's Stop Treating Our Youth Like Dummies. Editorial. ***Journal of Agricultural Safety and Health***, 24:2, 2018.

Issa, S.F., Nour, M.N., Field, W.E. Utilization and Effectiveness of Harnesses and Lifelines in Grain Entrapment Incident's; Preliminary Analysis. ***Journal of Agricultural Safety and Health***, 24:2, 2018.

Cheng, Y.H., Field, W.E., Issa, S.F., Kelly, K., Heber, M., Turner, R. Summary of U.S. Injuries and Fatalities Involving Entrapment and Suffocation in Grain Transport Vehicles. ***Journal of Agricultural Safety and Health***, 24:2, 2018.

Issa, S.F., Wassgren, C., Schwab, C.V., Stroshine, R., Field, W.E. Estimating Passive Stress Acting on a Grain Entrapment Victim's Chest. ***Journal of Agricultural Safety and Health,*** 24:3, 2018.

Nour, N.M., Field, W.E., Ni, J.Q., and Cheng, C. Development of Methodology to Document and Code Farm-related Injuries and Fatalities Involving Manure Storage, Handling, and Transport – with Summary of 2017 Incidents. ***Journal of Agromedicine***. 10.1080/1059924x2018. 1538420. 2018.

Nour, M.M., Field, W.E., Ni, J.Q., & Cheng, Y.H. (2020). Farm-Related Injuries and Fatalities Involving Children, Youth, and Young Workers during Manure Storage, Handling, and Transport. ***Journal of Agromedicine***, 1-11. doi: 10.1080/1059924X.2020.1795034

Nour, M.M., Cheng, Y.H., Ni, J.Q., Sheldon, Ed., & Field, W.E. (2021). Summary of Seven Central-state Region Injuries and Fatalities Involving Livestock Manure Storage, Handling, and Transport Operations: 1976-2019. (doi: 10.13031/jash.14343)

Nour, M. M., Cheng, Y. H., Field, W.E., Sheldon E., Ni J.Q. Summary of Known U.S. Injuries and Fatalities Involving Livestock Waste Storage, Handling, and Transport Operations: 1975-2019. ***Journal of Agricultural Safety and Health***. 2022 Jan 13;28(1):65-81. doi: 10.13031/jash.14615. PMID: 35130589.

Issa, S. F., D. Gaither, M.M.S. Raza, J. Lee, and Field, W.E., Removing Out-of-Condition Grain on Exploration and Documentations of Existing Strategies. ***Journal of Agricultural Safety and Health***. 2022, Volume 28 (4)

Nour, M. M., Y.M. Aly, and W.E. Field. A Novel Automated Tool for Monitoring Trends of Agricultural Waste Storage and Handling-related Inquiries and Fatalities Data in Real Time. **Safety**. 2022;8 (4): 75. https://doi.org/10:33901/safety8040075

Cheng, Y. H., W. E. Field, S. F. Issa, B. F. French, S. G. Ehlers, E. J. Sheldon. Documenting Baseline Efficiency of Grain Rescue Training for Emergency First Responders Through Pre- and Post- Testing and Follow-up Survey. ***Journal of Agricultural Safety and Health.*** 2024, Vol. 30. No. 3

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- www.agconfinedspaces.org
- http://apps.npr.org/buried-in-grain/
- www.grainsafety.org
- www.agsafety4youth.info