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RESEARCH AND EXTENSION AGENDA FOR

Agricultural Confined Spaces

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PREFACE

The United States Department of Agriculture (USDA) promotes high priority multistate research and education/extension activities through its land grant university system. Multistate research projects are managed by State Agricultural Experiment Station (SAES) directors in partnership with the National Institute of Food and Agriculture (NIFA) of the USDA, other research institutions and agencies, and the Cooperative Extension Service (CES). In this way, technological opportunities and complex problem solving activities, which are beyond the scope of a single SAES or land grant institution, can be approached in a more efficient and comprehensive way.

SAES directors are organized into four regional associations. One of these regional associations, the North Central Regional Association of Agricultural Experiment State Directors, approved the efforts of the North Central Region (NCR) 197 Committee on Agricultural Safety and Health Research and Extension in 2000. In 2005, this committee was re-appointed under the revised name North Central Education/Extension Research Activity Committee (NCERA) 197. The work of this committee is conducted under the project title "Agricultural Safety and Health Research and Extension" and published works are credited to the Committee on Agricultural Safety and Health Research and Extension. Though the NCR-197 and NCERA-197 committees were appointed by the North Central Region, the work scope and membership makeup is at a national level. The most recent project completed by NCERA-197 was the report on Agricultural Equipment on Public Roads, published in February of 2009 (http://www.nifa.usda.gov/nea/ag_systems/in_focus/workforce_if_equipment_public_roads.html).

NCERA committees provide opportunity for scientists, educators, technical specialists, and others to work cooperatively to solve problems that concern more than one state, share research data, and coordinate research, education, and other types of activities. Additionally, these committees serve to integrate education (academic and/or extension) and research on a particular topic where multistate coordination or information exchange is appropriate, has expected outcomes, conveys knowledge, and is peer reviewed. The desired outcome is to facilitate the transfer of research findings to practice in the most effective and economical manner. The duration of the committee may be up to five years. Committee membership is comprised of scientists and educators appointed by participating state research and extension directors, USDA representatives, and other professionals with appropriate expertise and interest.

In late 2010, NCERA-197 undertook the task of developing a research and extension agenda for agricultural confined spaces, with a special emphasis on confined spaces found on agricultural production sites currently exempt by OSHA safety and health regulations including CFR 29, Part 1910:146, Permit-Required Confined Spaces and CFR 29, Part 1910.272, Grain Handling Facilities. This topic had been identified as one of the 12 priorities for action in the National Land Grant Research and Extension Agenda for Agricultural Safety and Health: National Agenda for Action, published by the committee in 2003.

The committee solicited input from all land grant institutions concerning ongoing research and education efforts related to agricultural confined spaces and reviewed the published literature relevant to the topic. Drafts of a white paper focusing on the subject were prepared and reviewed by the committee and then presented to solicit feedback and generate increased awareness of the issues at several professional meetings, including the International Society of Agricultural Safety and Health (ISASH), June 2011, and 2012, and the American Society of Agricultural and Biological Engineers (ASABE), August 2011. Additional input was gathered from other professionals including Canadian agricultural safety organizations, at ISASH and

ASABE meetings held in the Summers of 2012 and 2013, and national symposiums on grain storage and handling safety held annually since 2012. Since the inception of the project, the committee has sought to maintain a dialogue within the land grant system on the hazards associated with agricultural confined spaces and to encourage research and extension activities designed to mitigate the hazards of these work spaces. This effort was considered a "work-in-progress" designed to generate an on-going response that would continue beyond the publication of a research or extension agenda.

It became apparent early in the process that the hazards and risks associated with confined spaces found in agricultural workplaces are complex and solutions will not be easily developed or implemented until all stakeholder groups become engaged in a long-term sustained effort. The NCERA-197 committee took on this project because it concluded that the topic is timely, problematic, wide-spread, and under-appreciated by agricultural producers and many in the agricultural safety and health community. Over the past five years, members of NCERA-197 Committee, along with others within the land grant system have undertaken an impressive array of research and extension activities that have added much to the understanding of the issues and raised national awareness of agricultural confined space hazards and the need to address them. The committee members hope the publication and dissemination of this document will provide enhanced understanding of the accomplishments that have been made and future direction that must continue in concert with public and private stakeholders to improve the safety and health of people working in agricultural production and related occupations who are exposed to agricultural confined spaces.

Activities/accomplishments that have taken place since the committee undertook this activity have been summarized in the Recommendations and Accomplishments section. The list of accomplishments clearly demonstrates the value of sustained collaborative activities of this type.

Committee on Agricultural Safety and Health Research and Extension
June 2016

ACKNOWLEDGEMENTS

The NCERA-197 Committee would like to thank the many people who provided input to the various drafts of this document. These include Steve Riedel, Salah Issa, and Charlene Cheng graduate research assistants at Purdue University, for the substantial effort in summarizing the fatality and injury data associated with confined spaces in agriculture reported on in this paper, Steve Wettschurack, Purdue's former agricultural emergency specialist, for his review and input on the extrication component, and Denise Heath, Kate Hamm, Chuck Baldwin, and Dawn Minns for the editorial assistance and layout.

In addition, the committee is thankful for the numerous comments received from members of ISASH, ASABE, and professionals representing the commercial grain industry. Their input was greatly appreciated.

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EXECUTIVE SUMMARY

The Committee on Agricultural Safety and Health Research and Extension was formed by the United States Department of Agriculture's Cooperative State Research, Education, and Extension Service (USDA-CSREES) North Central Regional (NCR) administrators in 2000. The goal of the committee, originally designated as NCR-197, was to more effectively use the land grant system's research and extension capacity in cooperation with the experience of those who live and work in agriculture to reduce work-related injuries, illness, death, and property loss. The NCR-197 Committee produced a landmark publication in 2003 titled, *National Land Grant Research and Extension Agenda for Agricultural Safety and Health: National Agenda for Action*. Twelve priorities for action were identified:

1. Sensors and guarding systems
2. Agricultural equipment on public roads
3. Agricultural confined spaces
4. Emerging technologies
5. Human factors engineering and design
6. Management of agricultural emergencies
7. Livestock handling and housing systems
8. Public policy issues
9. Capital and management intensive vs. family labor intensive operations
10. Fire detection and suppression
11. Agricultural safety education and training
12. Special populations and enterprises

In 2007, the committee, which had been renamed North Central Education Extension/Research Activity Committee (NCERA-197), began the process to develop a white paper on the use of agricultural equipment on public roads. This effort was completed in 2009. It was determined that the next primary issue to be addressed would be confined spaces in agriculture. This topic was considered at the time as a high priority due to the high fatality rates associated with incidents occurring in confined spaces, the lack of a comprehensive surveillance effort upon which to develop an evidence-based response, the confusion over exempt versus non-exempt facilities under the provisions of the Occupational Safety and Health Act (OSHA), and the recent occurrence of high profile incidents involving multiple victims. This activity was initiated in late 2010 with a decision to develop a whitepaper on the topic designed to generate discussion within the land grant system.

The white paper, which was distributed to key stakeholders in several drafts, had multiple purposes: a) to help identify research, public policy, and extension/outreach priorities for the land grant system, U.S. Departments of Labor and Agriculture, National Institute for Occupational Safety and Health, and agricultural production and commodity organizations; b) to identify possible engineering design and practice standards or guidelines to aid designers and fabricators of agricultural production facilities that contain confined spaces, for adoption by standard setting organizations (e.g. ASABE), and governmental regulatory agencies (e.g. state and federal OSHA); c) encourage needed research to address knowledge gaps regarding causes of injuries, fatalities, and illnesses related to the exposure to agricultural confined spaces; and d) to enhance the general awareness within the agricultural community concerning the potential risks associated with confined spaces in agriculture.

STATEMENT OF THE PROBLEM

Based upon the feedback from the drafts of the white paper and ongoing discussion of the issues by members of NCERA-197, a Research and Extension Agenda for Agricultural Confined Spaces was prepared. The hazards associated with agricultural confined spaces have historically been and continue to be significant causes of work-related injuries and fatalities within production agriculture (Field, 1979; Schwab, 1985; Kingman, 2001; Kingman, 2003; Beaver, 2007; Roberts, 2010; Riedel, 2013; Issa, 2013; Issa, 2014; Issa, 2015). In addition, these hazards contribute to a significant loss of livestock due to exposure to toxic environments in confined feeding operations brought about by the decomposition of livestock waste (Pesce, 2008). Agriculture ranks third, only behind the mining and oil and gas industries, in the number of documented fatalities occurring in confined spaces (NIOSH, 1994).[1] Since 1964, over 1,873 cases of injuries and fatalities have been documented in agricultural confined spaces (Issa, 2016). Of those, 1,156 (62%) cases were reported as fatal. This has included over 1,525 cases of engulfment, entrapment, falls, and entanglements in grain storage facilities; 143 cases of fatalities or injuries associated with manure storage structures; and 152 cases, mostly fatal, involving agricultural transport vehicles. These cases have been documented and catalogued in the Purdue Agricultural Confined Spaces Incident Database (PACSID). In addition, more than 184 other fatalities and injuries have been documented in a wide range of other confined spaces within agricultural settings including silos, sump pits, bulk tanks, wells, cisterns, and fermentation vessels (Issa, 2014). Over 95% of the victims are male, and approximately one out of five victims of all documented incidents were children and young adults under the age of 21. These data reflect only the very best case scenario due to the lack of fatality and injury reporting requirements for much of agriculture and the lack of comprehensive injury surveillance efforts. It has been estimated that the actual number of incidents is under-reported by as much as 30% (Roberts, 2010; Riedel, 2013). The insufficiency of data regarding causative factors contributing to confined space related injuries and fatalities in agricultural production is further complicated due to the lack of universally accepted definitions for agricultural confined spaces and the confusion or lack of clarity over the current interpretation of the agricultural workplace exemption language found in the relevant OSHA regulations (CFR Chapter 29, Part 1910.146 and CFR Chapter 29, Part 1910.272). Furthermore, due to the subjective nature often associated with the legislative or regulatory definitions and the diversity of scientific/engineering definitions, the development of an effective, targeted and sustainable response has remained somewhat elusive. If stakeholders, including the land grant system, are to develop a coordinated, interdisciplinary approach to enhancing the safety and health of workers exposed to agricultural confined spaces including both trained and untrained first responders,[2] better data are needed concerning the scope and magnitude of the problem and causative factors. There is also a need for common terminology that will aid in effective communications related to the topic and assessment of current intervention strategies, including public policy.

[1] It should be noted that the NIOSH data is now over 22 years old and there has been no new comparative data published. The ranking of agriculture may even be higher due to more aggressive enforcement of confined space entry standards that has occurred in the other two industries.

[2] Approximately one third of all documented incidents involving manure storage facilities are first responders.

DEFINITIONS

As noted, confusion exists regarding the definitions of what constitutes a confined space within an agricultural setting. Part of the confusion is the result of legislative language which exempts certain agricultural production sites (farms, seed processing facilities, and feedlots) from the enforcement of current confined space regulations, including both OSHA's, 29 CFR Part 1910.146 Permit-Required Confined Spaces Standard, and 29 Part 1910.272, Grain Handling Facilities Standard. This confusion is compounded when OSHA categorizes confined spaces into "permit-required confined spaces" and "confined spaces." For example, a "confined space" as defined by OSHA is:

- A space large enough and so configured that a person can bodily enter and perform assigned work; and
- A space that has limited or restricted means for entry and exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, or pits); and
- A space not designed for continuous human occupancy.

An OSHA "permit-required confined space" has the three characteristics defined by OSHA for a confined space plus one or more of the following:

- Contains or has the potential to contain a hazardous material (atmosphere)
- Contains a material that has the potential for engulfing an entrant
- Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section
- Contains any other recognized serious safety or health hazard

Under the OSHA definitions, most agricultural confined spaces, if found in any other industry, would fall under the current provisions of the two most relevant OSHA standards. However, due to clear exemptions in both laws, most of agriculture is exempt from the need to comply with the standards. Attempts by OSHA as recently as 2014 to expand their jurisdiction over certain agricultural workplaces, including high risk confined spaces, was strongly resisted by both agricultural organizations and members of Congress.

A "confined space" as defined by Washington State Department of Labor and Industries (WISHA) is:

- A space that is large enough to get a whole body inside
- A space that is not designed for human occupation
- A space that has limited or restricted entrance or exit

A space in Washington must have all three characteristics to be classified as a confined space. (It should be noted that state safety and health regulations can be more strict than the federal standards, but no less strict.)

A "confined space" as defined by the state of Maryland consists of a space:

- Having limited means of entry or egress; and
- So enclosed that adequate dilution ventilation is not obtained by:
  → Natural air movement; or
  → Mechanically induced movement; and
- Subject to:
  → The accumulation of toxic or combustible agents; or
  → An oxygen deficiency (the tested atmosphere contains less than 19.5% oxygen)

A "confined space" as defined by WorkSafeBC Occupational Health and Safety (OHS) Regulation (Canada) is a space that includes all of the following characteristics:

- An area that is enclosed or partially enclosed
- An area that is not designed or intended for continuous human occupancy
- An area that has limited or restricted means for entry and exit that may complicate the provision for first aid, evacuation, rescue, or other emergency response service
- An area that is large enough and so configured that a worker could enter and perform assigned work

The Agricultural Hazardous Occupations Orders (AgHOs) for agricultural employment, a part of the Fair Labor Standards Act (FLSA), specifically prohibits the employment of youth under age 16 to work in

specific types of confined spaces within agriculture. The prohibitions identified are specifically "working inside: (a) a fruit, forage, or grain storage designed to retain an oxygen deficient or toxic atmosphere[3]; (b) an upright silo within two weeks after silage has been added or when a top unloading device is in operating position; (c) a manure pit; or (d) a horizontal silo while operating a tractor for packing purposes. Once a youth reaches the age of 16, there are no specific restrictions for employment in exempt agricultural workplaces, including performing activities within confined spaces. This legal definition of a confined space, however, does not specifically mention grain storage bins where a toxic environment is generally not a problem. It appears that when the AgHOs were originally drafted, on-farm grain storage was not seen as a significant hazard. These spaces, however, account for the largest number of documented fatalities of youth under age 16 when exposed to agricultural confined spaces (Issa, 2016).

One informal definition that has been effective at communicating to workers what spaces should be considered confined spaces is:

"If you have to use your hands to get into it, it's a confined space."

Though not found in the technical or regulatory language, the use of such an easily communicated and understood concept helps increase the likelihood that it will be remembered in the workplace.

In summary, part of the effort of NCERA-197 to explore the hazards associated with agricultural confined spaces has included reviewing the various definitions used in the current regulatory language and by safety professionals, and attempting to develop common definitions that can be more widely understood by key stakeholders, especially within the land grant system. As noted, there is not currently a widely accepted definition for what constitutes an agricultural confined space. Grain bins, silos, and manure pits are all generally recognized as confined spaces, but a definition that is inclusive of the characteristics of all these facilities, and others found at agricultural worksites, was lacking at the time this effort was undertaken. The following definition was arrived at by the Committee and has been reviewed by numerous professionals, and is intended to add clarity to the discussion of confined spaces in agriculture and goes beyond the current regulatory definition used by OSHA for enforcement purposes.

An agricultural confined space is any space found in an agricultural workplace that was not designed or intended as a regular workstation, has limited or restricted means of entry or exit, and has associated with it potential physical and/or toxic hazards to workers who intentionally or unintentionally enter the space.

This definition is intended to include not only the widely accepted hazards such as entrapment or engulfment in free-flowing agricultural materials and asphyxiation due to toxic environments and limited oxygen, but also falls into or from confined spaces, entanglement in energized machinery located in confined spaces, and hazards to emergency first responders conducting rescue and recovery activities.[4]

[3] There are differences of opinion concerning the legality of youth under the age of 16 being employed in agriculture to enter a typical grain bin because the language of the FLSA is open for interpretation. Some safety professionals do not interpret the current language as applying to grain storage not designed to be oxygen limiting. However, the Grain Handling Standard (Part 1910.272) specifically prohibits certain activities such as being in a bin when unloading equipment is energized or "walking down the grain." Again, there is a lack of consistency since the FLSA only applies to youth employed in agriculture under the age of 16 while the Grain Handling Standard assumes a minimum employment age of 18, and does not apply to most on-farm grain storage facilities.

[4] The Purdue Agricultural Confined Space Incident Database was expanded in 2011 to include data on entrapments, engulfments, asphyxiations, entanglements, electrocutions, and falls in and around agricultural confined spaces.

EXAMPLES OF CONFINED SPACES IN AGRICULTURE

No comprehensive listing of types of confined spaces found on agricultural production sites was identified in the literature, primarily because most agricultural production sites are currently exempt from federal confined space regulations and the concept of a "confined space" is relatively unknown to many agricultural producers. The Department of Labor/OSHA provides a list of examples of confined spaces grouped by type of industry. This lengthy list of 23 industry types and examples of confined spaces, interestingly, does not include spaces generally found at agricultural production sites which, as noted earlier, are associated with the third highest number of fatalities documented in confined spaces. The list does include the general industry type of "Agricultural Services," but identifies only the following four types of confined spaces:

- Conveyor enclosures
- Diked areas around storage tanks
- Spray tanks
- Tanks

Based upon the definition developed by the NCERA-197 Committee, the OSHA classifications, a review of the literature, and an analysis of documented fatalities and injuries, several general categories and specific examples of confined spaces in agriculture have been identified. These spaces have been the site of a wide variety of incidents including entrapments, engulfments, asphyxiations, entanglements, falls, and electrocutions. They include:

1. Grain and Feed Storage Facilities
    - 1.1 Corrugated steel bins (all sizes)
    - 1.2 Steel tanks or silos
    - 1.3 Concrete silos
    - 1.4 Flat grain storage buildings
    - 1.5 Wooden feed storage structures
    - 1.6 Sumps and tunnels under storage facilities
    - 1.7 Dump pits
    - 1.8 Open grain piles
2. Forage Storage Structures
    - 2.1 Concrete stave and poured silos, including those designed to be oxygen limiting
    - 2.2 Wooden silos
    - 2.3 Steel/ceramic-oxygen limiting silos (e.g. Harvestore®)
    - 2.4 Horizontal or bunk silos
3. Manure Storage Structures
    - 3.1 Below floor storage pits and tanks
    - 3.2 Sump/pump pits
    - 3.3 Above ground manure storage tanks (e.g. Slurrystore®)
    - 3.4 Ponds, lagoons, and open pits, especially those with steep banks
    - 3.5 Manure/bio-digesters
4. Agricultural Transport Vehicles
    - 4.1 Grain transport vehicles (trucks, gravity bed wagons, auger carts)
    - 4.2 Manure transport vehicles (tanks and applicators)
    - 4.3 Food grade bulk transport vehicles (milk, juice, corn syrup)
    - 4.4 Sprayer and chemical transport vehicles
5. Agricultural Equipment
    - 5.1 Combine separation area
    - 5.2 Bale chamber on hay packaging equipment
    - 5.3 Forage and silage dump wagons
    - 5.4 Feed grinders/mixers
    - 5.5 Feed mixer wagons
    - 5.6 Cotton module builders
    - 5.7 Grinder/mixer machines and tub grinders
    - 5.8 Environmentally-controlled cabs/operator enclosures used to protect operators from toxic chemicals
6. Food Processing and Storage Equipment/Facilities
    - 6.1 Storage and mixing tanks, bins, and silos
    - 6.2 Fermentation vessels (pickling and wine vats)
    - 6.3 Environmentally controlled fruit and vegetable storage units
    - 6.4 Bulk liquid storage tanks (milk and juice)
7. Other
    - 7.1 Containment areas around diked storage tanks
    - 7.2 Trenches and other on-farm construction/excavation sites 4 feet deep or more
    - 7.3 Culverts
    - 7.4 Wells, cisterns, dry wells, septic tanks
    - 7.5 Grain driers
    - 7.6 Fuel storage tanks
    - 7.7 Greenhouses (during certain operations such as fumigation)
    - 7.8 Containment ponds

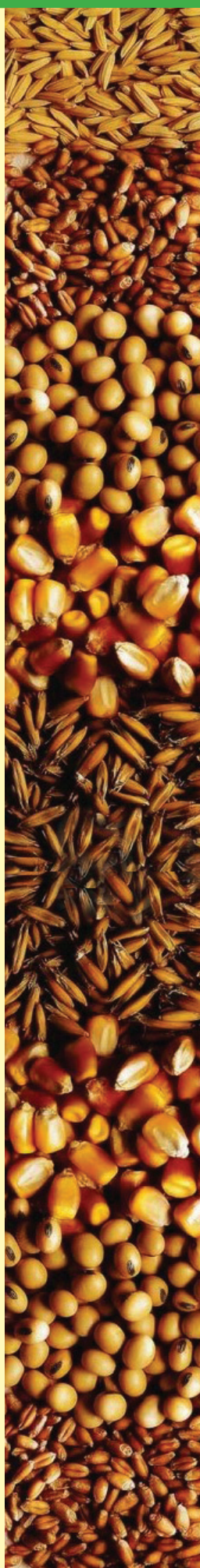
It should be noted that there may not be universal consensus on the previous listing of what constitutes an agricultural confined space. Some may argue that only spaces where compliance with federal and state workplace safety rules is required or that meet the specific criteria of a published technical definition should be included on the list. Others questioned inclusion of sites such as the inside of feed grinders, greenhouses, trenches, diked containment areas, and spaces within agricultural equipment, each of which has been the site of documented agricultural workplace fatalities and injuries. Still others may not recognize the inclusion of falls associated with confined spaces and some of the literature separates out incidents of equipment entanglement from under the umbrella of confined space-related hazards. The purpose of incorporating these non-traditional forms of confined spaces-related incidents is not to inflate the frequency or rate of injuries or fatalities associated with confined spaces in agriculture, but rather to raise the awareness of the hazards of these sites, learn as much as possible about the comparative risks and ensure development of more comprehensive intervention strategies. For example, in some cases an engulfment inside of a grain storage facility or asphyxiation in a manure storage structure may have been preceded by an unintentional fall from a poorly designed or maintained ladder or other work surface. Or, an entanglement in a sweep auger in a grain bin presents unique issues for emergency first responders who must enter the bin to rescue or recover the victim. By including these related incidents, researchers and educators will be able to better understand the larger picture and respond more effectively.

HAZARDS ASSOCIATED WITH CONFINED SPACES

Analysis of fatalities and injuries associated with confined spaces in agriculture over the past 40 years have identified the following potential hazards to workers exposed to these sites (Issa, 2015; Issa, 2016):

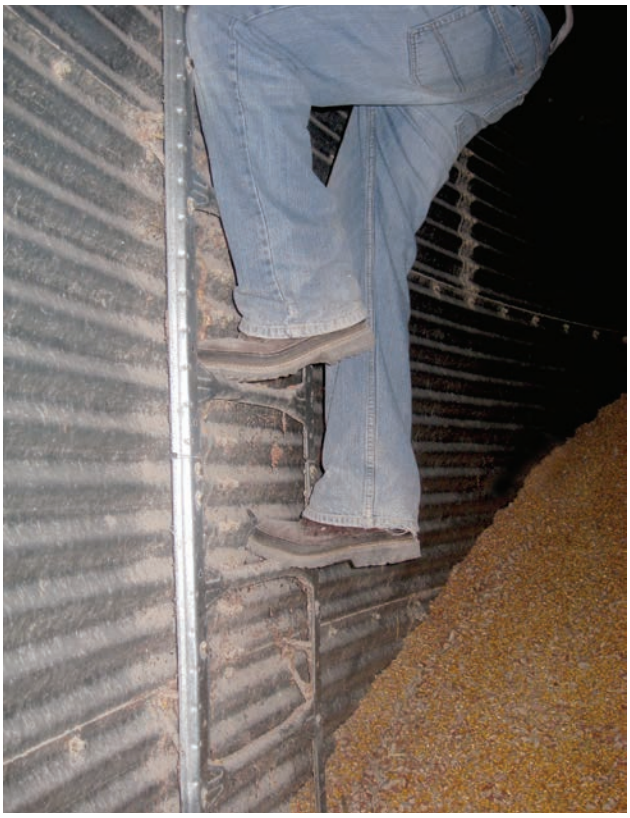
1. Entrapment and engulfment in loose or free flowing agricultural materials (e.g. grain, silage, feed, seed, fertilizer) within storage structures or transport vehicles resulting in suffocation or injury. This type of incident accounts for the single largest share of all documented incidents.
2. Suffocation/asphyxiation within a confined space due to exposure to toxic gases or insufficient levels (<19.9%) of oxygen. The largest percentage of these incidents are related to manure storage and handling.
3. Drowning in liquids present within the confined space, including manure pits and lagoons.
4. Injuries associated with entanglement in energized components within the confined space. The primary agents are in-floor augers, sweep augers, and stirring augers.
5. Acute respiratory distress due exposure to toxic dust, molds, and other airborne hazards.
6. Falls into confined spaces or from structures containing confined spaces.
7. Heat stress/exhaustion due to high temperatures within confined spaces.
8. Hypothermia due to extended engulfment/entrapment in chilled grain or environmentally controlled spaces.
9. Injuries caused by first responders to victims during extrication efforts from a confined space.
10. Injuries to first responders attempting to conduct rescue and recovery operations in and around confined spaces.
11. Explosions and fires associated with confined spaces where flammable liquids are stored or flammable dust or gases are present.
12. Exposure to excessive noise levels within the space.
13. Post-traumatic psychological conditions related to entrapment and extrication.

This may not be an exhaustive list of potential hazards or provide the best categorization. For example, it does not include the use of certain confined spaces and their related hazards as a means to commit suicide as have been documented in the case of oxygen-limiting silos.



CASE STUDIES

A review of online sources reveals hundreds of cases reported by the media on incidents involving agricultural confined spaces. In addition, well documented case studies have been made available through NIOSH's Fatality Assessment and Control Evaluation (FACE) Program that investigates all types of workplace fatalities. The following keywords can be used to locate reports of confined space incidents for further review: "grain entrapment," "buried in grain," "grain bin entrapment," "death in manure pits," "confined spaces," "suffocation in flowing grain."



SUMMARY OF CURRENT CONFINED SPACES IN AGRICULTURE INCIDENT DATA

Comprehensive data regarding the frequency, severity, and contributing factors associated with fatalities and injuries in agricultural confined spaces does not exist. There is no requirement to report such incidents to a central depository nor is there a process in place to conduct epidemiological analysis of these events on a consistent basis. There are however sources of data that allow for a relatively good understanding of certain components of the problem. These include NIOSH's FACE Program reports and annual summaries published from the Purdue Agricultural Confined Space Incident Database (PACSID). The FACE Program was established by NIOSH to investigate selected occupational fatalities, including those occurring in agricultural workplaces. A review of the most recent FACE reports for the period 1985-2015 identified fairly comprehensive summaries of no fewer than 18 incidents involving agricultural confined spaces resulting in 23 fatalities. These reports provided good descriptions of the nature of the fatalities and contributing factors. No overall summary of these cases had been prepared and contacts with NIOSH staff did not result in the identification of more recent cases. NIOSH staff noted that the problems of confined spaces in agriculture had been well defined by the agency and that more emphasis needed to be placed on intervention strategies than on additional data collection.

The primary data source reviewed was the PACSID which currently contains data on over 1,873 fatal and non-fatal cases involving agricultural confined spaces. These cases included entrapments, engulfments, asphyxiation, entanglements, falls, and electrocutions documented over the period 1964-2015. The database was derived from newspaper and media reports, NIOSH FACE reports, individual state farm injury summaries, prior litigation documents, and official documents such as death certificates and police reports. The Purdue database, though incomplete, is the largest known database of incidents involving agricultural confined spaces. The magnitude of the database allows for relatively reliable observations to be made about the nature of certain aspects of the problem.

However, the lack of comprehensive data, especially on non-fatal cases, over the time frame covered by cases in the PACSID, and the substantial changes in exposure data (e.g. the dramatic increase in the number of grain storage structures and manure pits and declining number of upright silos and farm workers) prevents reliable estimations of rates for specific types of incidents. Even considering these and other limitations of the data set, this source provides the best available picture of the problem and was used to develop the following summary of these incidents.

Figure 1 provides an annual distribution and ten-year moving average of the documented cases involving all types of agricultural confined spaces that occurred between 1964 and 2015 (Riedel, 2013; Issa, 2013; Issa, 2014; Issa, 2015; Issa, 2016). The increasing frequency between 2007 and 2014, as shown by the ten-year average of these events, could be attributed to several factors, including enhanced surveillance efforts, greater public awareness of the problem, and increased exposure to confined spaces due to the increased use of confined spaces in new agricultural construction, especially on-farm grain storage and confined livestock feeding facilities. Since 2013, the ten-year average has been declining, even as surveillance efforts have become more aggressive. However, this decline can largely be attributed to an unusually low number of cases documented in 2012 and 2015.

Figure 2 provides a breakdown of the type of facilities involved in each of the 1,873 documented cases[5] analyzed by Issa (2016) for the period 1964-2015 using the categories established during the design of the database. As noted, grain storage and handling facilities accounted for approximately three-fourth of all documented cases.

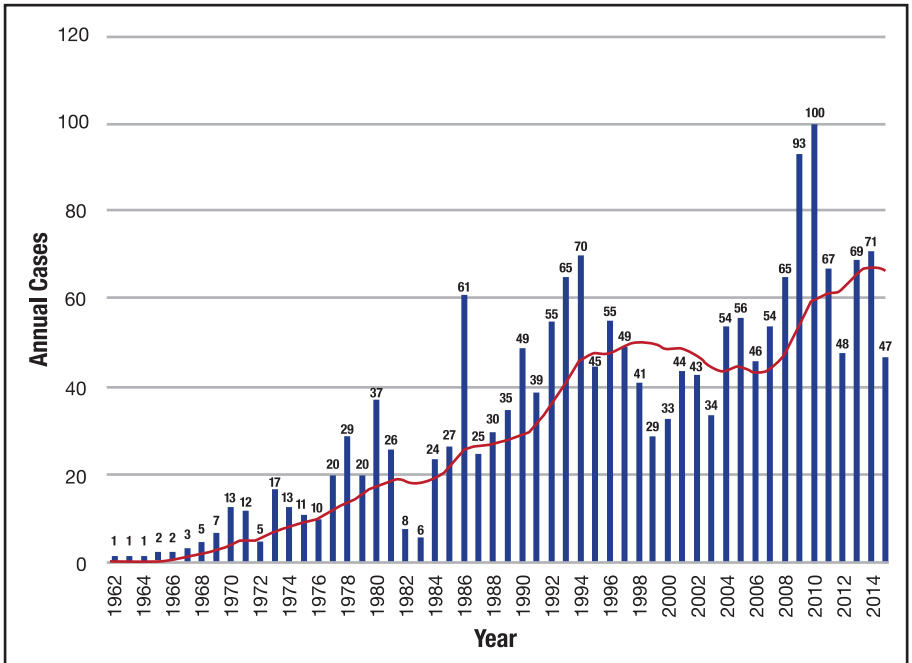


Figure 1: Annual Distribution of Documented Cases in Confined Spaces in Agriculture with a Ten-year Moving Average, 1964-2015 (N=1,873)

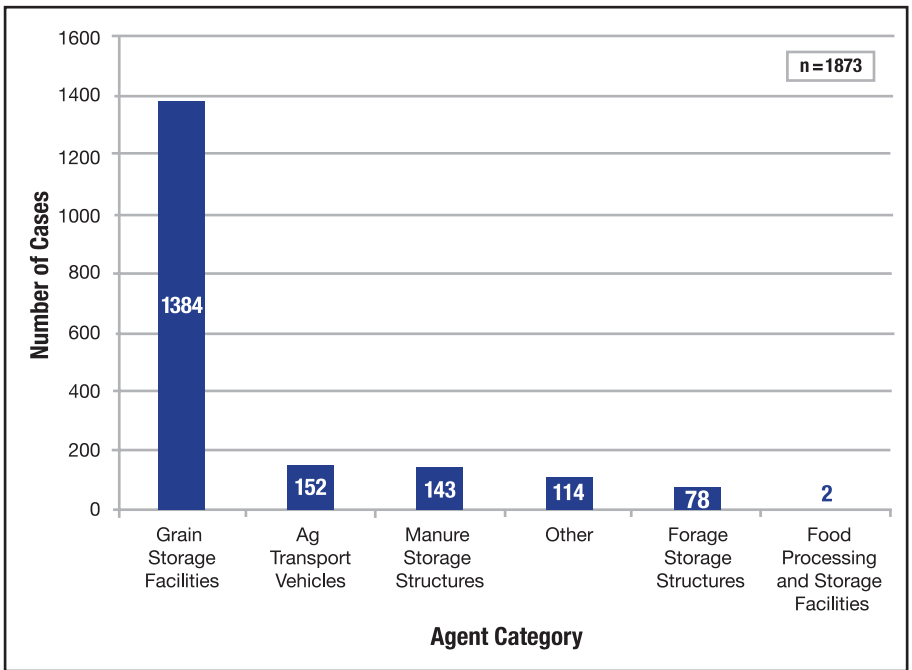


Figure 2. Distribution of Agricultural Confined Spaces Cases by Agent Category, 1964-2015 (N=1,873)

[5] Each case in the database represents one individual or victim. In some incidents there were multiple victims or cases. In two incidents involving manure storage, for example, there were five victims in each or a total of 10 fatalities.

The geographic distribution of all documented cases, when known, is shown in Figure 3. The majority of cases occurred in what is generally known as the Corn Belt. States with the most documented cases were Iowa, Indiana, Minnesota, Illinois, Wisconsin, and Nebraska. There is a direct correlation between the amount of grain stored on farms, exempt from current OSHA workplace safety regulations, and the number of documented incidents. Each of these states have also had historically strong agricultural safety and health programs with fairly strong injury surveillance efforts which may have contributed to higher numbers of documented cases.

Males accounted for over 96% of the total and children under the age of 16 accounted for nearly one out of six cases (15%)[6], as reported in Figure 4. In one unusual case, two female children died while attempting to rescue their father who became overcome by toxic gases in a confined space. Grain transport vehicles were a significant agent in cases resulting in child-related fatalities. The average age of these incidents was approximately 11, with nearly all being male. Overall, over one out of five cases involved individuals under the age of 21 (22%).

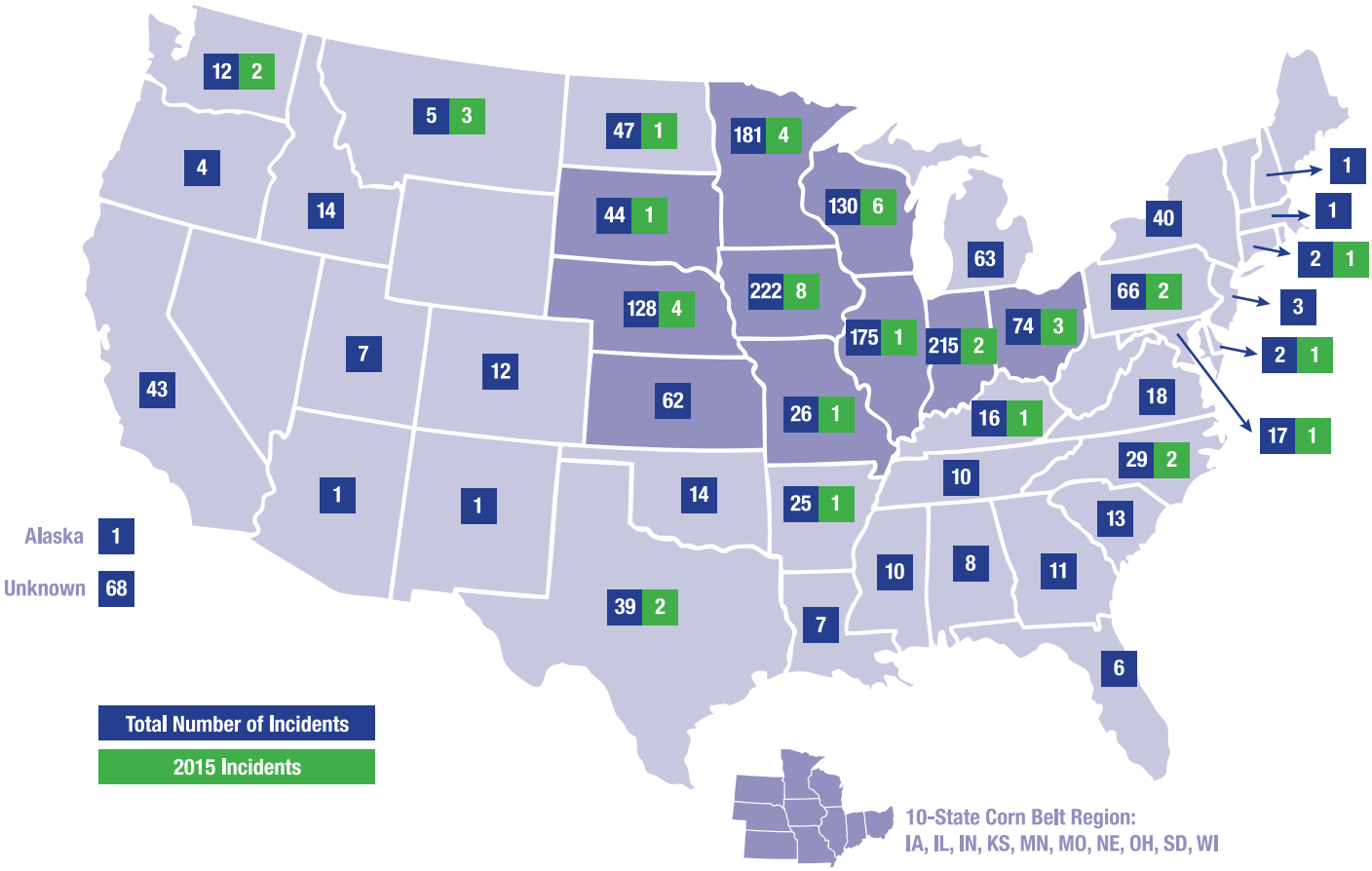


Figure 3. Distribution of Agricultural Confined Space-related Cases by State: 1964-2015 (N=1,873)

[6] The high percentage of children and young worker involvement is of interest due to the strict prohibition of children under the age of 16 from being employed to work in agricultural confined spaces under the provisions of the FLSA, or under the age of 18 at OSHA non-exempt commercial grain operations. The data suggest that the majority of child-related incidents occurred on OSHA exempt farms, feed lots, and seed processing facilities or involved the children of farm operators exempt from the FLSA.

Also noted in Figure 4 is the distribution of fatal to non-fatal incidents. Of the 1,873 cases, 1036 or 63% resulted in a fatality. This high fatality rate may have more to do with the lack of reporting of non-fatal incidents. Of special note, however, is the finding that of the 235 incidents involving children under the age of 16, 167 or slightly more than 71% were fatal. The number of fatal cases in 2015 exceeded the number of non-fatal cases for all types of confined spaces. The decline in documented cases is primarily due to a decline in the number of non-fatal cases being identified.

The data for documented cases involving grain storage and handling; livestock manure storage and handling; agricultural transport vehicles; forage storage structures; and auger entanglements in agricultural confined spaces, are summarized in the following four sections.

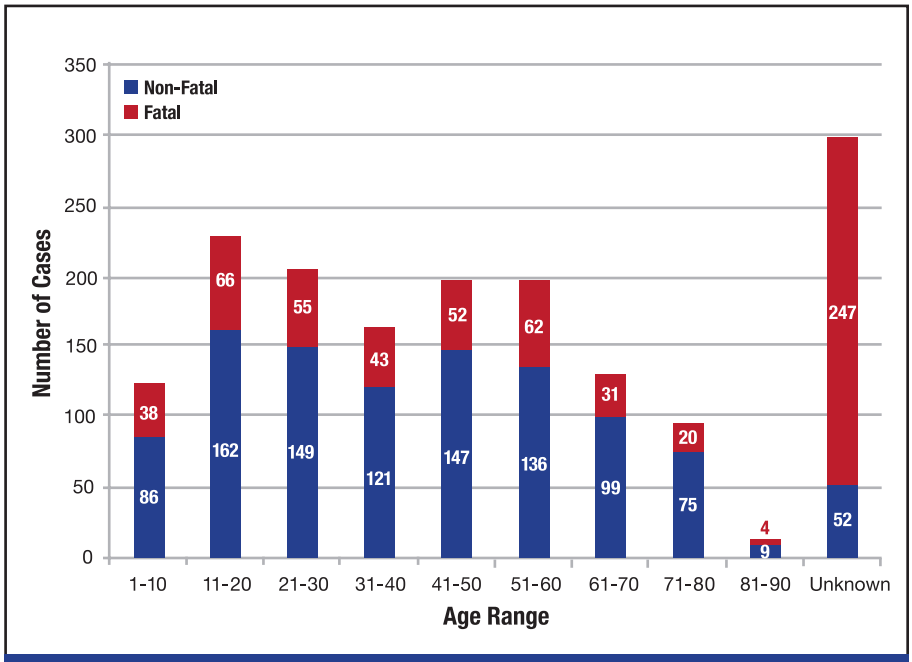


Figure 4. Fatal vs. Non-fatal Number of Agricultural Confined Space Cases per Age Range, 1964-2015 (N=1,873)

SUMMARY OF GRAIN STORAGE AND HANDLING INCIDENTS

Over 1,525 fatal and non-fatal grain storage and handling-related cases, including those involving grain transport vehicles, have been documented and entered into the PACSID, which accounts for over 80% of all documented confined space-related cases in the database. In 2010, no fewer than 59 grain entrapments and engulfments occurred in the U.S. This was the highest number ever documented.[7] Of the 59 grain-related cases, approximately half were fatal and half were non-fatal. The annual total dropped to 33 and 23 in 2011 and 2012 respectively and increased again in 2013 to 33 and 38 in 2014. The 24 cases in 2015 was the lowest since 2012 and second lowest in over a decade. Figure 5 provides the five-year average between 2003 and 2015, which shows the problem is trending downwards as with many other types of farm-related fatalities and injuries. It should be noted that historically, approximately 70% of grain-related cases have occurred on OSHA-exempt farms, while 30% have occurred at non-exempt commercial facilities. There is no significant trend since the mid-1980s, with the exempt cases oscillating between 40% to 60% of all cases where the OSHA-exemption status was known. Nearly all the victims have been male with a median age of 39. Indiana, Iowa, Illinois, Minnesota, Wisconsin, and Nebraska have accounted for the majority of grain-related cases.

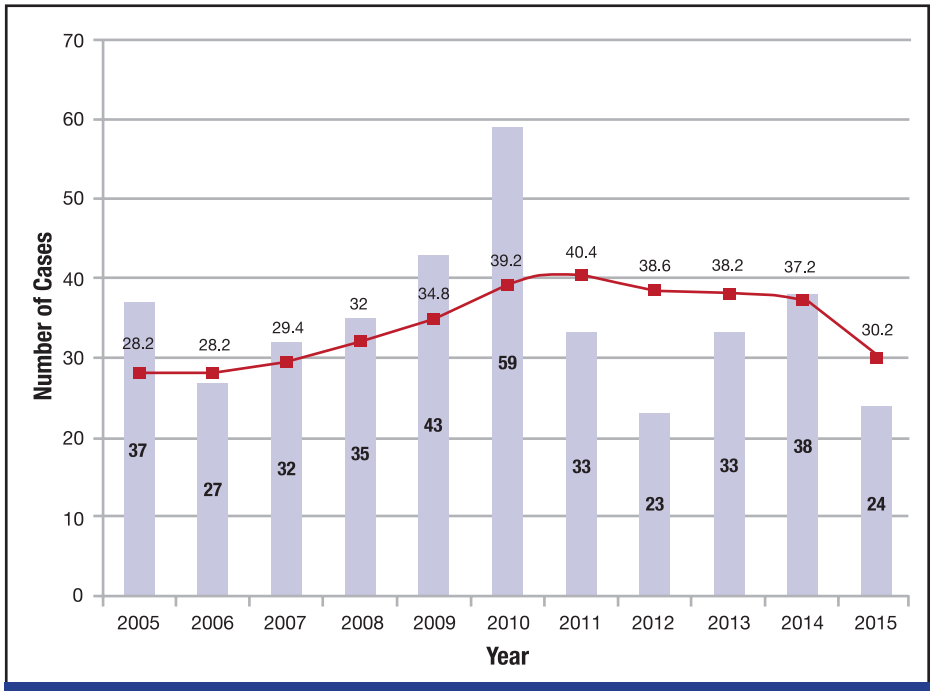


Figure 5: Number of Annual Fatal and Non-Fatal Grain Entrapments and the 5-year Average, 2005-2015 (N=384)

In 2010, the peak year, there were seven youth under the age of 16 involved in entrapments, of which six were documented as fatalities. In 2011, 2012, and 2013, 2014 and 2015 there were 0, 1, 0, 5, and 3 respectively. The primary medium, reported in almost 50% of all cases, when known, was corn (including seed corn, popcorn, and ear corn) and the primary cause leading to entrapment was entering the storage facility to loosen or breakup crusted, spoiled, or frozen grain while unloading equipment was operating.

This practice, known as "walking down the grain" is specifically forbidden under current OSHA regulations. It has been shown that there is a direct correlation between the presence of out-of-condition grain and the increased likelihood of entrapment (Kingman, 2004).

[7] The original 2010 summary identified 51 documented incidents with an additional 8 cases added in the three subsequent years. This reflects the fluid nature of the database due to a lack of comprehensive surveillance efforts.

SUMMARY OF LIVESTOCK MANURE STORAGE AND HANDLING CASES

Of all agricultural confined spaces cases, 143 (8%) of documented injuries or fatalities involved livestock manure storage or handling facilities. Approximately half of the cases occurred on dairy operations and almost one out of five involved children under the age of 16. The most frequent (34%) activity at the time of death was conducting repairs or maintenance activities on manure handling equipment, such as pumps, while the second most frequent activity (22%) was attempting to perform a rescue of another person entrapped or overcome in a manure storage space (Beaver, 2007). In other words, over one out of five victims was either an untrained or trained first responder attempting to aid an initial victim. The most frequently identified cause of death documented was asphyxiation with elevated levels of sulfide in the blood, due to exposure to hydrogen sulfide, noted in some cases. In others, the official report identified "methane poisonings" as the cause of death which is questionable due to the higher probability for the presence of and higher toxicity of hydrogen sulfide. In two reported incidents, five fatalities were reported in each case and there were numerous incidents where multiple victims were documented, most of whom, again, were untrained first responders. The peak period of incidents was during the hottest part of the summer and often associated with agitating liquid manure prior to transferring it from storage to transport or application equipment (Beaver, 2007 and Zhao, 2007).

More recently, there have been a growing number of reports of foaming manure in storage facilities associated with livestock, especially swine confined feeding operations. This build-up of toxic and flammable gases has been reported as contributing to fires, explosions and loss of life and livestock. The causes of this condition are still being explored, but may be influenced by the type of feed being fed, larger amounts of manure being stored for longer periods of time, and use of bedding material containing gypsum. (Ni, 2009; Jacobson, 2013; Fabian-Wheeler, 2015).

SUMMARY OF CASES INVOLVING AGRICULTURAL TRANSPORT VEHICLES

A total of 152 cases were documented in which the victim was inside an agricultural transport vehicle such as a grain transport vehicle, truck bed, rail car, or liquid manure transport tank. All but five cases involved grain transport with most of the victims being male children, with an average age of 11, who became entrapped or engulfed during loading and unloading operations. The frequency of these events has continued to decline since the 1990s with no cases documented in 2012 or 2013, (Cheng, 2014).[8] Substantial public awareness campaigns regarding this particular hazard to children, conducted by organizations such as Farm Safety 4-Just Kids, and the Progressive Farmer Safety Day Camps, may have contributed to this reduction in the frequency of incidents.

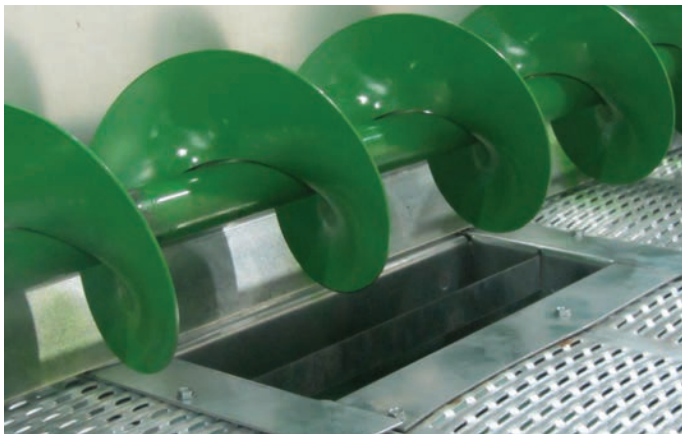
[8] Though not a U.S. case, three young girls suffocated in Canada in a gravity flow grain wagon of canola in 2015.

SUMMARY OF CASES INVOLVING FORAGE STORAGE STRUCTURES (SILOS)

No fewer than 78 cases, or about 4% of the total documented cases, involved an individual on or inside a forage storage structure. This included primarily upright or vertical silos that were both open and oxygen limiting. Over 94% of the victims were male and almost 70% of the cases were fatal. The average age of the victim was 35 years old and asphyxiation or silo gas poisoning accounted for 50% of the cases. The number of these incidents appears to be on the decline due to the diminishing use of upright silos on beef and dairy operations, and increased use of silage bagging equipment or bunk silos.

AUGER ENTANGLEMENTS INSIDE CONFINED SPACES

Entanglements in energized equipment, including augers found in agricultural workplaces, have historically been a significant cause of traumatic injury. Incidents involving augers located inside agricultural confined spaces, primarily grain storage structures and forage silos, although relatively rare events, are a widely recognized problem due to the relative severity of the resulting injuries and the complexities of victim extrication. The problem, however, is neither well documented nor elucidated in the research literature other than anecdotal observations relating to medical treatment of auger-related injuries and citations for non-compliance with federal and state workplace safety regulations. A review of the 1,650 cases documented in the PACSID identified 167 cases involving an entanglement in energized augers that occurred while the victim was working inside an agricultural confined space (Cheng, 2016). These incidents primarily included in-floor unloading augers, sweep augers, stirrators, and auger components found on silo unloaders. Incidents involving portable tube augers used to handle grain outside grain storage structures were not included in the summary. Based on analysis of the data, approximately 98.2% of known victims were male, with the 21 to 45 age group most vulnerable to injury. Approximately one third (32.3%) of incidents were fatal, and lower limb amputation was the most frequently reported injury type. It is believed that non-fatal incidents are grossly under-reported in the data set. The type of augers identified most frequently (48) as the agent of injury were exposed in-floor augers that frequently caused the amputation of one or more lower limbs when the victim stepped into an unguarded opening or well in the floor of the confined space. The primary reason identified as to why workers were exposed to energized augers in the cases documented was to assist in the removal of residual grain. The large number of cases (36) involving augers on top unloading silo unloaders was not anticipated. Silo unloaders also accounted for the largest number of documented fatalities (15) of any entanglement type. It is believed that incidents involving silo unloaders are significantly under reported in the PACSID.



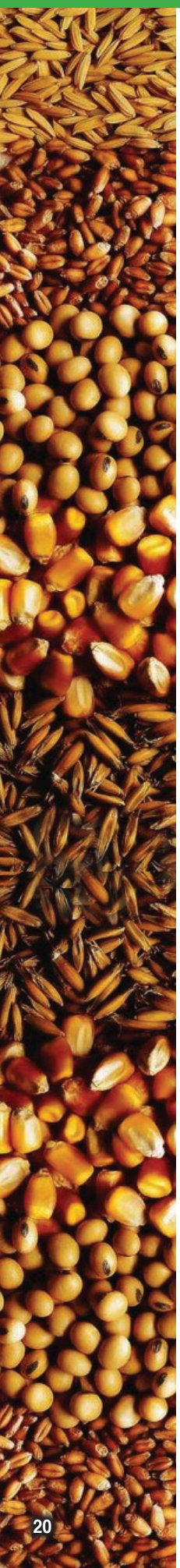
RESPONDING TO AGRICULTURAL CONFINED SPACE-RELATED EMERGENCIES

The Cooperative Extension Service has been engaged in training rural emergency first responders for nearly four decades. The focus of this national effort has been on enhancing the capacity to respond to agricultural emergencies, including entrapments, engulfments, and entanglements in agricultural confined spaces. In the late 1970s, a collaborative effort involving Cornell University, Purdue University, University of Nebraska, The Ohio State University, and Pennsylvania State University developed "Farm Accident Rescue" (Baker, 1982, 1986, 1999), the first book on responding to agricultural emergencies. This publication was later revised twice and over 135,000 copies were distributed nationwide for use in first responder training. Contents included specific recommendations for responding to various types of confined space incidents, including those involving manure pits, silos, and grain storage structures.

It is estimated that several hundred thousand fire/rescue, emergency medical, law enforcement and other emergency management personnel have been trained by land grant institution staff on topics ranging from responding to pesticide and anhydrous ammonia spills, to handling livestock after a disaster, to grain bin and manure storage rescues. This training has been supplemented with relevant Extension publications, websites, rescue simulators, and train-the-trainer curricula. In some cases the information has been adopted as best practices for emergency agencies, such as the procedures for evacuating grain from a bin during rescue operations and the use of grain rescue tubes to protect entrapped victims. More recently with support from an OSHA Susan Hardwood grant, Purdue University developed a seven-hour first responder training program specifically addressing agricultural confined spaces. Between 2011 and 2015, over 3,000 first responders from over 10 states completed the training. In addition, over 65 first responder instructors completed the training and were provided instructional resources to conduct the training on their own.

Land grant universities have also been involved in conducting research to enhance the effectiveness and safety of first response strategies. This has included determining the forces involved in extricating a victim entrapped in grain (Roberts, 2012; Roberts, 2015), methods for extinguishing silo fires, development and testing of the first commercially available grain rescue tube (Kingman, 2004), and use of grain vacuum machines to expedite a grain bin rescue (Field, 2014).

One issue that the attention given to emergency management of agricultural incidents has raised is determining the appropriate allocation of resources between prevention or mitigation of these incidents, and response to related emergencies and enhancement of emergency response capabilities. For example, review of current web-based resources on grain storage and handling safety suggests that there has been a greater investment of resources made on emergency preparedness and response than prevention, especially on OSHA-exempt farms. This emphasis was also evident in the initial drafts of the proposed ASABE engineering standard on grain storage bins that was intended to enhance the safety of these facilities. There is a need for continued dialogue on how best to utilize limited available resources on reducing the frequency and severity of agricultural confined spaces incidents as well as responding to them.



REVIEW OF CURRENTLY AVAILABLE EDUCATIONAL RESOURCES/ACTIVITIES

The following is a partial review of current educational resources and training being offered by the land grant system and other members of NCERA-197 at the time the research and extension agenda was prepared. It is not considered a comprehensive list of activities, but provides a base line to compare future initiatives. For additional information on the availability of resources and training contact the local Extension office or Extension Safety Specialist at the state's land grant institution.

1. Arkansas
- → Released grain safety Extension publication both in print and electronic formats
- → Provides grain rescue training for emergency first responders
- → Promotes best practices for managing grain quality

2. Georgia
- → Provides fire rescue training that covers agricultural confined spaces

3. Illinois
- → Established grain safety coalition
- → Provides fire rescue training that covers agricultural confined spaces
- → Developed confined space curriculum for agribusiness service providers
- → Developed new curriculum and conducted training for farmers and young and beginning workers in the grain industry with support from the OSHA Susan Harwood Program
- → Conducted research on incorporating appropriate anchor points in grain storage bins
- → Produced new audio visual materials on grain storage and handling safety
- → Promoted development and use of manure pit foaming safety decal

4. Indiana
- → Maintains agricultural confined spaces incident database
- → Proposed first grain bin engineering safety standard
- → Developed 7-hour grain rescue certification class for emergency first responders with support from the OSHA Susan Harwood Program
- → Developed first commercially available grain rescue tube
- → Conducted grain quality and flowing grain hazard training for farmers
- → Conducted an initiative to install over 15,000 safety decals on grain bins
- → Extension publications on grain handling and manure storage safety
- → AgHOs curriculum includes agricultural confined spaces
- → Established www.agconfinedspaces.org
- → Interactive grain safety-related displays
- → Developed and tested new curriculum for young and beginning workers in the grain industry with support from Susan Harwood Program

5. Iowa
- → Extension publications on grain handling and manure storage safety
- → Grain bin tug-a-war exhibit
- → 4-H and youth curriculum on grain safety, adopted by National 4-H
- → Training emergency first responders

6. Missouri
- → Extension publications on grain handling and manure storage safety
- → Produced grain safety video
- → Interactive grain safety tug-a-war exhibit
- → Training emergency first responders on grain entrapment

7. New York
- → Agricultural confined space hazard awareness training for emergency first responders and farmers

8. Ohio
- → Provides 2-day training for grain rescue/bin training
- → Provides 1-day general, grain rescue class
- → Extension publications on grain safety
- → Designed and built a portable grain rescue simulator

9. Oklahoma
- → Developed grain safety video
- → Provides grain rescue training for emergency first responders
- → Working on new grain bin engineering standard

10. Pennsylvania
- → Conducted manure storage/ventilation systems research
- → Developed ASABE Standard on manure storage ventilation and online design tool
- → Developed comprehensive education program to address manure storage hazards
- → Provides confined space rescue training for emergency first responders
- → Conducts educational programs on hazards of flowing grain
- → Developed AgHOs curriculum that addresses agricultural confined spaces
- → Established www.manurepitsafety.psu.edu

11. Utah
- → Conducted research on the perceptions of farmers towards agricultural confined space hazards

12. Virginia
- → Established taskforce to address manure storage incidents

13. Wisconsin
- → Conducts programs on grain handling and manure storage hazards
- → Investigation hazards related to biodigesters
- → Provides confined space rescue training
- → OSHA compliance for large dairy operations

14. NIOSH
- → Special hazard alerts on grain handling and manure storage safety
- → Questions on confined spaces in agriculture included in farmer survey
- → FACE Reports

15. National Corn Growers Association/National Grain and Feed Association
- → Made available video on-line
- → Released new video on grain safety

16. Canada (British Columbia)
- → Conducts training for farmers to comply with confined space regulations
- → Developed educational resources on agricultural confined spaces
- → Developed a hazard assessment template for agricultural confined spaces
- → Conducted a 60-hour training program for safety coordinators
- → Targeted training toward the mushroom and dairy industries
- → Conducted a one-day conference on confined spaces in agriculture

17. Canada (Ontario)
- → Produced fact sheets on confined spaces
- → Produced video on confined spaces in agriculture
- → Conducted training on agricultural confined spaces

The common denominator for all of the programs reviewed was the lack of funding to conduct sustained outreach efforts to the most vulnerable populations. Many of the activities were conducted with short term grants or as a part of larger projects that once completed ended the outreach efforts. Currently, there are no sustained educational or engineering efforts underway to raise the awareness of the hazards of agricultural confined spaces or enhance the safety of these facilities.

RESEARCH AND EDUCATIONAL GAPS

A review of published information on confined spaces in agriculture identified the following research and educational needs that, if addressed, could enhance the safety of agricultural workers exposed to confined spaces.

1. Documenting the influences that motivate workers to enter confined spaces in agricultural workplaces knowing that the risk level for fatal or serious injury is high and addressing these influences through training or enhanced engineering designs.
2. Documenting the perception of risks held by agricultural employers and workers concerning confined spaces.
3. Documenting the factors that contribute to children and younger workers under the age of 16 intentionally or unintentionally entering confined spaces in agriculture, and explore possible barriers or practices that would inhibit such access.
4. Validating the most effective hazard alert messages, including level of severity, for agricultural confined spaces for incorporation into warning signage and operator/user instructions based upon the level of risk and best management practices. There is currently no standard, universally recognized safety signage for agricultural confined spaces.
5. Documenting the economic impact of bringing current exempt confined spaces in agriculture into compliance with the basic or minimum best work practices or federal requirements for general industry confined space entry (29 CFR Part 1910.146) and grain handling (29 CFR Part 1910.272).
6. Identifying the engineering, political, social, and economic barriers that exist for enhancing the safety of confined spaces in agricultural workplaces or bringing them into compliance with current federal safety and health standards.
7. Developing and disseminating evidence-based educational resources on best grain management practices that would reduce the risk of grain going out of condition thereby reducing the risk of entrapment or exposure to other confined space hazards.
8. Documenting the efficacy of current grain rescue strategies including the use of high angle and confined space rescue teams, breaching grain storage structures, activation of aeration equipment, use of temporary or emergency rescue anchor points, use of grain retaining devices such as rescue tubes, and application of grain vacuum equipment.
9. Exploring strategies designed to reduce the potential of first responders from being injured or killed attempting to conduct confined space rescues or recoveries without appropriate training or equipment.
10. Developing more affordable and/or acceptable techniques for reliably testing and monitoring air quality in agricultural confined spaces.
11. Developing new strategies for removing residual material or product from grain storage structures and completing sanitation activities that would reduce the need to have workers enter the space.
12. Documenting the causes of falls in and around agricultural confined spaces and the development of more effective fall prevention strategies, including new engineering design standards.
13. Examining the use of augers and other energized components used inside of agricultural confined spaces and their guarding by means of shields and lockout/tagout systems.
14. Investigating the contributing factors leading to the rapid release of toxic gases in manure storage facilities and possible mitigation practices such as enhanced ventilation, sensors, and low level agitation of storage.
15. Exploring the use of emerging technologies, including remote or wireless surveillance and monitoring systems, "smart bin" technology, and unmanned aerial vehicles to reduce human exposure to agricultural confined spaces and allow for earlier detection of hazardous conditions such as grain spoilage and the presence of toxic gases.

NEED FOR RELEVANT ENGINEERING AND PRACTICE STANDARDS

The Occupational Safety and Health Act (OSHA) is the primary source of regulations that govern occupational safety and health in the U.S. OSHA currently has standards that govern entry into confined spaces, including grain storage facilities, but production agriculture (farms, feed lots, and seed processing facilities) has been specifically exempted from these standards (Code of Federal Regulations, 1987 and Code of Federal Regulations, 1993). Consequently, there are approximately 700,000 grain bins on over 306,000 farms that do not need to meet any current workplace safety regulations and often are unaware of accepted best safe work practices.

Attempts to remove those exemptions have been unsuccessful for political and economic reasons. These standards contain engineering controls that potentially could reduce the risk of working in grain storage facilities regardless of the exemption status of the site. The American Society of Agricultural and Biological Engineers (ASABE) is the professional society that develops and publishes safety-related engineering standards and practices in agriculture (ASABE, 2015). An engineering standard contains definitive terminology, specifications, and performance criteria or procedures relating to design, testing, and performance of materials, structures, and products. Engineering practice standards address practices, standard operating procedures, or guidelines accepted as appropriate, proper, and desirable for general use in design, installation, or utilization of systems or system components. ASABE standards have been a driving force behind enhanced safety of agricultural machinery and facilities, and have been a significant reference source for OSHA standards, such as for standards related to Roll Over Protective Structures (ROPS), Slow Moving Vehicle Emblems (SMV), and guarding of agricultural equipment.

The 2016 ASABE Standards suggest there are more than 60 engineering practices or standards that are safety related. However, very few relate directly to the hazards of confined spaces in agriculture. Engineering Practice 470, Manure Storage Safety, addresses practices around manure storage facilities that help (a) minimize the hazards of manure gases to livestock and humans, and (b) minimize potential for drowning at manure storage sites (ASABE, 2011). This engineering practice was first published in 1992 and revised in 2011. Other standards that would be relevant to certain aspects of confined spaces include those related to warnings, guarding of machine components, and ladders and walking surfaces.

A second engineering standard related to manure storage, ANSI/ASABE S607, *Ventilating Manure Storages to Reduce Entry Risk*, has been adopted (ASABE, 2010). The purpose of the standard is "…to reduce risk from asphyxiation, poisoning and explosions when entering confined space manure storages by specifying the positive pressure, forced ventilation requirements, including ventilation system layout, air exchange rates, and minimum ventilation times, for evacuation of contaminant gases from, and replenishment of oxygen into, empty or nearly empty covered or partially covered confined-space, on-farm, manure storages, reception tanks, agitation tanks and other similar containers that hold/contain manure prior to entry." This standard recommends layouts of storage facilities, systems to maintain positive pressure, and mechanical ventilation systems for a wide range of confined-space manure storage facilities commonly found on livestock facilities in the United States.

The adoption of a general grain bin standard has yet to be accomplished.[9] Consequently, many well documented safety concepts that could have reduced the risk of entrapments, engulfments, asphyxiations, entanglements, and falls have not been incorporated into the design of these structures.

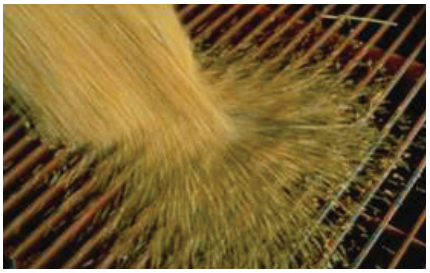
In 2003 a farm grain bin safety standard was proposed and considered by ASABE. The purpose of the standard was to improve personal safety of owners, operators, and others who may be involved in the normal storage, conditioning, cleaning, and servicing of corrugated steel grain bin storage structures. The scope of the proposed standard was intended for the design, installation, and access of round, bottom-unloading, stationary, metal, grain storage bins used to store or condition grain. The proposed standard was not approved by the originating committee due to the perceived cost of implementation. In 2011, a new initiative within ASABE was undertaken, partially as the result of influence from NCERA-197, to reintroduce a standard for grain storage structures. A proposed standard was submitted for consideration but was, again, not approved. The focus of the proposed standard was initially towards provisions to better enable emergency first responders to extricate entrapped victims rather than injury prevention. Revisions were made to refocus the proposed standard on prevention oriented measures. This effort has a strong representation from the land grant system.

The absence of adequate design criteria for the manufacture, fabrication, installation, and use of agricultural confined spaces, in general, is problematic. This is especially true with respect to safe access, uniform safety signage, fall prevention, appropriate anchor points, provisions for locking out energized components and provisions for removing residual grain.

[9] ASABE is in the process of finalizing a grain bin engineering standard. It is anticipated that it will be published in 2016.

COST OF COMPLIANCE WITH EXISTING CONFINED SPACE REGULATIONS

While it would undoubtedly be beneficial if all employers, including farm and ranch operators, would comply with the various OSHA confined spaces-related standards, and provide their employees with a safe and healthful place to work, there is, however, a widely held view among the currently exempt agricultural (non-industrial) sector employers (i.e., farmers) that the cost of complying with the current OSHA standards would be prohibitive. Furthermore, under the current marketing model under which grain is sold, there is no means to pass along the cost of compliance to consumers as there is in general industry (O'Conner, 2012). For example, the cost of monitoring workers within a confined space while the job is in progress, the development of procedures and practices for safe entry operations, installation of compliant anchor points, the implementation of procedures to coordinate confined space rescue operations, and other costs of compliance would be excessive for most of the 306,000 (USDA, 2015) individual farms and ranches that store grain, and would adversely affect farm income. Compliance would also require on-going maintenance costs such as the annual calibration of air quality measurement devices, purchase of personal protective equipment, annual education and training of employees, and contractual agreements with external confined space rescue services. In many cases, the cost of retrofitting confined spaces would exceed the value of older structures and force their removal from service. The burden on smaller farms would be especially high. Compliance with OSHA's Permit-Required Confined Spaces and the Grain Handling standards would require an enormous change in the way that farmers, currently exempt from the standards, do business. Legislatively requiring compliance would not be economically feasible without substantial financial incentives within the current marketing model for agricultural commodities.



RECOMMENDATIONS AND ACCOMPLISHMENTS

The NCERA-197 Committee in 2014 drafted a list of eight recommendations or actions that should be taken to address the gaps with respect to research, education, engineering standards and practices, and public policy needed to reduce the frequency and severity of injuries associated with agricultural confined spaces. The following is a list of these recommendations and a partial summary of accomplishments that have been completed to date with respect to each recommendation (accomplishments are identified).

1. NCERA-197 should facilitate national or regional symposiums on the topic of agricultural confined spaces and invite researchers, educators, and other stakeholders to review the findings of this effort and to explore strategies for prioritizing and implementation of its recommendations.

ACCOMPLISHMENTS:

- NCERA-197 committee members have been involved in promoting and presenting at no fewer than three national grain rescue symposiums (2011, Assumption, IL, 2012, St. Louis, MO and 2014, Normal, IL with 60, 186, and 240 participants, respectively).
- NCERA-197 collaborated with Great Plains Center for Agricultural Health and Safety (University of Iowa) on conducting a national symposium on agricultural confined spaces in Cedar Rapids, IA, November 14-16, 2012. Over 120 attended.
- NCERA-197 members have presented on agricultural confined spaces at ISASH, ASABE, ASCA, GEAPS, Farm Bureau Meetings, Michigan Safety Conference, Indiana Trauma Conference, and other professional meetings reaching over 800 professionals.

2. There is a need to continue the current surveillance and documentation efforts for agricultural confined space incidents that build upon the Purdue Agricultural Confined Space Incident Database.

ACCOMPLISHMENTS:

- Purdue has published annual summaries of grain entrapments in the U.S. for 2008-2015. Available at www.agconfinedspaces.org.
- Incidents involving all agricultural confined spaces (entrapments, engulfments, asphyxiations, entanglements, falls, and electrocutions) are now being included in the database.
- The Susan Harwood Grant (OSHA) to Purdue University allowed for more aggressive surveillance from 2011 through 2015.
- Articles summarizing the frequency, severity, and primary causative factors associated with injuries and fatalities involving confined spaces in agriculture have been published. These include: (Roberts, 2011; Riedel, 2013; Field, 2014; and Issa, 2016).
- Additional articles have been prepared and published related to: children and confined spaces (Issa, 2015); grain rescue strategies and hazards associated with the use of grain vacuums (Field, 2014); and entanglements inside of agricultural confined spaces (Cheng, 2016).

3. Additional in-depth study is needed on hazards identified by the currently available data as being potentially high risk to agricultural producers, their families, and workers. These include:

- The reasons behind the high exposure of children especially young males to agricultural confined spaces.
- Falls from or into agricultural confined spaces.
- Extrication strategies for entrapments in agricultural confined spaces.
- Practices designed to prevent out-of-condition grain that contribute to entrapment.
- Removal of residual material in storage facilities.
- Exposure to energized equipment inside confined spaces.
- Expanded use of grain vacuum machines.
- Barriers to complying with confined space entry procedures in on-farm settings.

ACCOMPLISHMENTS:

- Summary of incidents involving grain vacuum machines was presented at ISASH June 2012 and published in JASH (Field, 2014).
- Summary of confined space incidents involving children and youth was presented at ASABE meeting, August 2012, and published (Issa, 2016).
- Summary of extrication strategies used for entrapments in grain storage facilities published (Roberts, 2011; Roberts, 2015).

- Summary of research on cost of meeting OSHA compliance requirements for currently exempt grain storage facilities was presented at ASABE, August 2012.
- Findings on manure pit ventilation studies presented at ASABE and published in JASH by Pennsylvania State University (Murphy, 2014).
- Summary of 167 documented injuries involving energized sweep and unload augers inside of grain storage structures presented at ISASH and published (Cheng, 2016).
- Pennsylvania State University surveyed farmers with confined space manure storages for work exposures, safety practices and risk perceptions. (Murphy and Manbeck, 2014)
- Utah State surveyed farmers on confined space work exposure and risk perceptions (Pate, 2014).
- NIOSH has conducted farm surveys on exposure to confined spaces.
- Pennsylvania State University faciliated new ASABE standard on ventilation of manure storage spaces (Manbeck, 2016).

4. Development of evidence-based educational strategies are needed that address the most significant contributing factors to entrapments and injuries in and around agricultural confined spaces. This could include:

- Development of agricultural confined spaces educational websites.
- Production of online webinars on agricultural confined spaces related hazards and intervention strategies.
- Design of curricula that address high risk populations such as farm families with children, children living near confined spaces, young and beginning workers at small commercial grain storage facilities, etc.
- Incorporation of additional content on agricultural confined spaces in the Hazardous Occupation (AGHOs) training Agricultural curriculum.
- Develop teaching resources to put on the National FFA curriculum website.

ACCOMPLISHMENTS:

- There are now several new confined space websites in operation: www.grainsafety.org, www.grainquality.org, www.agconfinedspaces.org, www.grainentrapmentprevention.com, and www.manurepitsafety.psu.edu. All have input from land grant associates. In addition, hundreds of documents have been added to the web related to agricultural confined spaces.
- FReSH eXtension site on agricultural safety and health has information on grain storage and handling safety, respiratory hazards, grain dust explosions, manure storage hazards, confined space rescue and monitoring toxic gases, www.extension.org/farm_safety_and_health
- Land grant grain drying and storage committee developed new resources for grain management that includes a safety component.
- New Extension publications on grain safety have been produced by University of Arkansas, Purdue University, Illinois Grain Safety Coalition, and Iowa State University.
- Illinois, Indiana, Pennsylvania, Ohio, and Iowa now have grain bin rescue training simulator sites for use with first responders.
- New videos on grain storage and handling safety were produced by the National Corn Growers Association and National Grain and Feed Association, Oklahoma State University, and Illinois Grain Safety Coalition.
- An estimated 225 in-service classes on grain bin rescue have been conducted in the Corn Belt by Extension staff targeting emergency first responders.
- Penn State University, Iowa State University, Ohio State University and Purdue University have developed educational displays on grain safety that have been exhibited at major farm shows and other public awareness events reaching hundreds of thousands of attendees.
- GEAPS/Kansas State have developed three online modules on grain safety (GEAPS 545-Grain entrapment, causes prevention, and rescue). Targets non-exempt facilities.
- Purdue University/Kansas State developed, tested, and disseminated a curriculum for training young and new employees under an OSHA Susan Harwood grant.
- Grain Handling Safety Coalition/University of Illinois developing community-based training resources under an OSHA Susan Harwood grant.
- Purdue University developed a seven-hour course on the basics of responding to grain entrapment under an OSHA Susan Harwood grant. Available at www.agconfinedspaces.org.
- Land grant contributions to development of enhanced owner/operator instructions provided by manufacturers of grain storage facilities.

- Iowa State's Grain Bin Tug-a-war safety display has been replicated by several states and used at major farm events including a long term display at the Indiana State Museum.
- Penn State University developed a mobile safety ventilation demonstration unit, two videos on safely ventilating manure storages; and four fact sheets addressing confined space manure storage safe practices (Tillapaugh, 2010 and Murphy, 2014).

5. A review of all current relevant agricultural confined spaces engineering standards and practices should be carried out and revisions considered to address significant causative factors based upon the currently available injury and fatality data.

- Current standards were reviewed and summarized in Riedel, 2011 and O'Conner 2012 research.
- Land grant personnel are involved with current ASABE efforts to develop a new consensus engineering standard for grain bins.

6. Where adequate engineering standards and practices don't currently exist, the appropriate standards organization (e.g. ASABE) should be encouraged to undertake the development of new standards that address the current causes of injuries and fatalities in agricultural confined spaces. Standards are needed to address:

- Safer access into confined spaces.
- Need for uniform identification of confined space hazards.
- Monitoring of hazardous conditions within confined spaces.
- Removal of residual grain without the need for exposure to energized augers and conveyors.
- Ladders, working surfaces, and platforms in and around agricultural confined spaces.
- Appropriate anchor points for fall prevention and rescue procedures.

ACCOMPLISHMENTS:

- Penn State facilitated new ASABE standard on ventilation of manure storage spaces.
- ASABE committee has been established to work on an engineering standard for grain storage structures to be submitted to ASABE for consideration. NCERA-197 Committee members represented in the process.
- Increased hazard awareness has led to increased presence of warning labels on grain vacuum machines.

7. Enforcement of current federal workplace safety regulations, related to confined spaces, at non-exempt facilities such as small commercial grain storage facilities should continue.

- Enhanced OSHA enforcement is occurring at non-exempt facilities.
- Purdue University, Ohio State University, and University of Illinois have conducted training for OSHA compliance staff.

8. A review of current federal workplace safety regulations are needed to explore a broader, voluntary application of these rules to currently exempt facilities that contain confined spaces. This would require cost/benefit studies of compliance, need for retrofitting or replacement of current facilities, and capacity for education and enforcement.

- Study completed on estimating the cost of retrofitting representative grain storage facilities at currently exempt facilities to meet the applicable OSHA standards (O'Conner, 2012).

RESOURCES

As part of Purdue University's OSHA Susan Harwood grant, an extensive review of the literature was conducted to identify resources related to agricultural confined spaces. This search resulted in a list of several hundred items including peer reviewed journal articles, educational publications, curriculum materials and audio-visual products. This list can be reviewed at www.agconfinedspaces.org.

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An agricultural confined space is any space found in an agricultural workplace that was not designed or intended as a regular workstation, has limited or restricted means of entry or exit, and has associated with it potential physical and/or toxic hazards to workers who intentionally or unintentionally enter the space.

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