Engineering and Technology – Buildings and Structures

Dick Steffen, Ph.D.
Department of Plant, Soil and General Agriculture
Southern Illinois University
Carbondale, IL.

Introduction

Despite involving only around 2% of the population of the United States, farming has a fatality rate that consistently ranks it as one of the three most dangerous occupations (National Safety Council, 1999, 2000; Murphy, 1998). Of further concern is the Ag injury rate, which, due to a lack of an accurate reporting system, is difficult to accurately determine. Becker (1992) estimated the number injured at 120,000. NIOSH and the Marshfield Medical Research and Education Center (1996) place the number at 210,000 and 200,000 respectively. While the number may be disputed, most agree on the need to attempt to reduce the number of injuries in agriculture.

In 1990, one of the first concerted efforts to develop a focused plan for reducing fatalities and injuries in agriculture was undertaken and resulted in the report Agriculture at Risk. One of the major outcomes of Agriculture at Risk was to identify needs and recommendations for action for research, education and policy efforts in agricultural safety and health. Three general needs were identified:

1. The development of systems to address the lack of preventative, diagnostic and rehabilitative services in agriculture.
2. Additional education at all levels, from child to older farmers, including spouses, workers, and other family members, as well as professionals such as agriculture teachers, extensions workers and physicians.
3. The need for more research and professional coalitions starting with leadership provided by the federal government.

Recommendations were formulated in each of four major areas. These included:

1. Legislative initiatives - 22 general and specific agenda items were listed at both the federal and state level.
2. Occupational Health and Safety Delivery Initiatives - Eight specific pilot projects were identified to begin developing a comprehensive program.
3. Education was again a major focus of the recommendations with six major recommendations and 15 sub-categories.
4. Developing Coalitions contained three recommendations.

Much progress has been made on initiating many of the recommendations that were made. New educational programs, coalitions have been created and research undertaken. However, much work remains to be done. One area the appears to need additional work is the area of safety and

health issues related to agricultural structures.

Most fatalities are still a result of exposure to tractors and machinery, while livestock have been identified as a major cause of non-fatal injuries. The number of injuries associated with agricultural structures is difficult if not impossible to determine since most tracking systems classify (or at least report) the incidents according to the injury agent, such as falls, livestock, suffocation or other rather than by the location. While the data may be available, few if any efforts have been made to extract that information from the databases. In addition, the role the structure itself plays in the incident is not always clear. However, any thorough examination of the status of safety on US farms would not be complete without an examination of the injury situation in and around agricultural structures.

In this discussion, we will examine typical farm structures, look at some recent research, identify safety and health issues and offer recommendations for future research and training efforts. For purposes of ease of discussion, in this paper, I will include farm family members as farmers. Workers are non-family members hired as full-time, part-time and seasonal workers.

Uniqueness of Production Agriculture Work Sites

When compared to other industries, farming has a number of unique attributes that confound efforts to address safety and health issues. Among these attributes are:

1. Remoteness of the Work Site

Because farms are widely dispersed geographically, in many cases, the agricultural worker, whether the farmer himself, an employee, or an employee of an outside worker will be working alone. This means:

-- an injured worker may not have the means to summon aid for him or herself.
-- it may be hours before the injured worker is discovered.
-- it may take longer for emergency services to arrive then their urban counterparts.

In addition, since volunteers staff many emergency services in the rural community, aid may be delayed further because:

-- volunteers must first respond from their own remote locations to be dispatched to the scene.
-- the local emergency services may not have adequate equipment to deal with a particular emergency, and may have to call for assistance from other towns.

2. Lack of Regulations

Agriculture has been exempted from many regulations related to safety and health issues, the most notable of these being agriculture's exemption from the Occupational Safety and Health Act (OSHA) of 1970. This means that in the case of a family farm that hires no outside workers, few OSHA regulations apply (Kelsey, 1994).

Other safety and health regulations in agriculture, such as the Hazardous Occupations Order for Agriculture (HOOA) apply only to a specific sub-population (children) and often contain exemptions for members of the farm family (Murphy, 1992). This lack of regulations contributes to the high number of injury rate in agriculture. In addition these exemptions create situations in which workers (i.e. equipment dealer technician, salesperson, etc) that are covered, must enter a work area that is not covered by the regulations. This means that since farmers themselves are not subject to the provisions of the standards and may be unaware of the regulations, unsafe and dangerous conditions may exist. Outside contractors that provide services on-the-farm need to be aware of this potential and take appropriate precautions.

3. Unique Environments

Agriculture also has a number of unique environments not found in an industrial setting such silos, grain bins, and manure pits. There is often less control over those environments since many involve biological processes, conditions within may change, depending on a number of factors over which the farmer, or the worker have little control. In order to be able to perform their jobs safely, farmers and workers need to be familiar with these settings and their characteristics.

Structures in Agriculture

Structures play a critical role in agriculture. They house our raw materials, finished product, equipment and livestock. They provide a place to work and shelter from the elements. Agriculture utilizes a wide variety of structures. Each of these types of structures has its own characteristics, strengths, weaknesses, pros, cons and each creates unique safety issues with which producers must contend.

Since structures represent a major capital investment for most producers, many buildings will be in use for long periods of time, often well past obsolescence. This longevity also confounds efforts to improve safety and health in farming because it slows the adoption of newer, safer designs. One illustration of this problem is the number of agriculture buildings still in use with electrical wiring that does not meet current code and often does not include the safety grounding wire, creating a potential electrocution hazard. This longevity in building use may also create hazards as buildings are modified and adapted to meet rapidly changing production systems. If these modifications are done without benefit of a thorough understanding of the engineering and safety issues raised by the modification, serious safety hazards may be created. An example of this type of activity is the conversion of old barns to machinery storage. Significant modifications are often made to the structure. Without consideration to the changes in the loads on the building members the modification creates, unsafe conditions may be created.

Along these lines, a recent trend in Southern Illinois is interest in converting swine confinement buildings to other uses. Work has been done evaluating the possibility of using these structures for aquaculture, and in other cases, swine buildings have been adapted to corn storage. Again, these conversions create potential for unique safety hazards that should be addressed before the conversions are completed.

Structures in Ag Safety & Health

Since structures play a major role in agriculture, they also have the potential to have a significant influence on the safety and health of farmers and workers. However, ascertaining the extent of the involvement of structures in injury incidents is more difficult. Few studies list structures as either an injury agent or clearly define it as being involved in the incident.

Most injury tracking systems, when reporting their findings, classify injuries according to the type or source of injury. Therefore the cause of an injury may be reported as falls, animals, being struck by an object or a similar category without reference to the location of the injury (National Safety Council, 2000; Hard, et al. 1999; Gelberg, et al. 1999; Shireley & Gilmore, 1995). One study that referenced injuries to structures was Pahwa et al. (1995) who found that nearly 24 percent of farm accidents in Saskatchewan occurred in farm buildings. Other studies seek to study injuries to specific types of structures. For example, Kelly and Field (1996) looked at grain engulfments and determined that 73% of flowing grain related entrapments occurred in grain bins. These types of studies can provide us a clearer idea of the extent of injury incidents within a particular structure, but few have been completed on structures such as sheds and barns.

References to structures are more likely to show up in research that seeks to evaluate the safety of a specific worksite. For example, Murphy et al. (1998) conducted an audit of farms using an instrument designed to give an idea of the relative safety of the farm sites evaluated. They had specific questions that related to conditions in and around agricultural structures including the presence of such items as fire extinguishers, housekeeping, safe storage of fuels, electrical systems and warning decals. The researchers used the audit to create a "percent of optimal" rating which indicated the percentage of operators who had the best rating for a particular item. A high rating indicates a low hazard condition. They found that less than a third of farms audited had an optimal hazard rating for most of the items examined. Assuming that a less than optimal rating corresponds to an increased level of risk of injury present, their results suggest that hazardous conditions are relatively widespread in and around farm structures.

Since location of the injury incident is often not reported, it is difficult to get a clear picture of just how much of an impact structures have on the ag injury problem. However, we can get an idea of the extent of the problem using current Ag injury data. For example, logic would suggest that a large portion of Ag related injuries that result from falls likely occur in and around structures. Likewise, the category "Caught in or crushed in collapsing materials" used by the National Safety Council, is likely to contain a large proportion of incidents involving engulfment by grain and other agricultural materials.

Often, the number of these incidents that are directly attributable to a given type of hazard, such as a grain bin, cannot be determined without significant effort. When information is available, it is often the result of specific research questions dealing with a unique hazard within structures systems. For example, Kelly and Field (1996) examined fatality reports to identify incidents attributable to grain transport vehicles and storage structures. They determined that 235 work-related fatalities involved grain entrapment between 1970 and 1993. They further categorized these incidents into three groups, bin/silo, grain transport vehicle and other. Their research found

most fatalities (173) occurred in bins and silos. Further studies of this nature will be needed to get a better understanding of the current injury situation related to structures.

Without thorough access to fatality and injury data, it is nearly impossible to create a clear picture of the extent of the agricultural injury problem attributable to structures. However, research that has been conducted, as well as data collected by the Centers for Disease Control (CDC) and from such projects as the Sentinel Project Researching Agricultural Injuries Notification System (SPRAINS), does begin to provide an idea of the extent of the problem. More research will be needed to thoroughly understand the problem.

Discussion

There are a wide variety of different types of hazards associated with agricultural structures. Some hazards are unique to a specific structure, and others may be common across all agricultural structures. The general hazards associated with agricultural structures include:

-- Slips and falls (from heights or the same elevation)
-- Being struck by objects
-- Engulfment by stored materials
-- Crushing by stored materials
-- Electrical shock
-- Atmospheric hazards
-- -- Toxic gasses
-- -- Dusts and molds (farmers lung)
-- -- Asphyxiation
-- -- Biological hazards
-- -- Pathogens
-- Rodents and insects
-- Fire and flammable materials
-- Poor lighting
-- Weather
-- Mechanical hazards
-- -- Machinery
-- -- Automated equipment
-- Poor housekeeping

Many of these hazards are associated with confined spaces. NIOSH has identified confined spaces as a workplace hazard needing particular emphasis and has issued several alerts to address these sites, including particular attention to agricultural environments (NIOSH, 1994). A confined space, as defined by OSHA, has three characteristics. They:

1. are large enough and configured for an employee to enter and work.
2. have limited or restricted means of entry or exit.
3. are not designed for continuous human occupancy.

While these confined spaces present hazards that must be understood to safely work in and around them, OSHA further identified spaces that had unique characteristics. These spaces are often referred to as Permit Required Confined Spaces (PRCS) and under OSHA's guidelines, can only be entered by developing and following a plan addressing the hazards found in that space. The characteristics of a PRCS, under OSHA's Confined Space Standard (29 CFR 1910.146) are:

1. It contains or has a potential to contain a hazardous atmosphere;
2. The space contains a material that has the potential of engulfing an entrant;
3. It has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a small cross-section, or
4. The space contains any other recognized serious safety or health hazard.

Obviously, many agricultural spaces fit this definition. Once again, the family farm was exempted from the PRCS standard (OSHA 2001). Not surprisingly, agriculture ranks second behind Mining and Oil and Gas industries in the number of fatalities associated with Confined Spaces (NIOSH, 1994).

While family farm are exempt, other Ag entities, such as implement dealers and feel deliver personnel must follow the provisions when working on one of these farm sites whether they have any control over the spaces or not. This creates a dilemma for the ag services employer. A farmer requests a service call to his farm. Upon arrival, the service person determines they cannot attempt the necessary service without some extensive repairs being conducted to the site before he enters to correct obvious safety hazards. The service provider will either enter the space disregarding the hazards, violating workplace rules and subjecting himself to potential injury and his employer to fines, or he can refuse to enter until the farmer has had the safety problems corrected, in which case the service provider may anger the farmer-customer, resulting in a loss of good relations and probably a loss of business as farmers shift business to other service providers who might not follow appropriate safety procedures. This may also cause the farmer to undertake service that he may not be capable of undertaking safely.

More significantly, the farmer and his family members and employees face these same hazards every day, most often with little knowledge of the extent of the procedures deemed necessary to safely enter these areas. As such farmers and their families often enter spaces containing significant safety and health risks without taking even the most basic precautions. Since farmers may be exposed to these hazards many times without incident, it is often difficult to overcome the biases created by these exposures when attempting to educate the farmer of the dangers faced and the convince him or her of need to take appropriate safety precautions.

Another major concern is the concern about the health effects of chronic and acute exposure to atmospheric conditions found in many structures such as bins, silos and livestock buildings. Since these exposures are being dealt with in depth in other portions of this program, these issues will not be covered here:

-- Specific structures their associated hazards and concerns
-- Machinery storage / repair structures.

These seemingly innocuous structures are not often a focus of safety efforts. If we exclude injuries due to machinery, the major safety hazards associated with these structures include:

-- slips and falls from heights (storage lofts),
-- falls from same heights (due to debris and spills from poor housekeeping)
-- fire hazards associate with fuels and solvents
-- hazards from stored chemicals
-- asphyxiation due to operating engines and/or shop processes without proper ventilation

Other hazards may include lack of fire extinguishers, poor electrical wiring, inproper use of extension chords, crush hazards from doors and leaning objects and sparks from metal working (Cyr & Johnson, 2001)

Perhaps one often-unidentified hazard is associated with chemicals and materials stored in these facilities temporarily, particularly in case of fire. The producer may forget or not realize the potential danger of these materials, such as pesticide in a planter stored in the shed. During a fire, he could place himself, his workers and emergency personnel at risk if he does not recognize the potential hazard created by this situation.

Barns and Livestock Facilities

In these facilities, the biggest danger is likely injury from livestock. Again, a discussion of those hazards is left to other presenters in this program.

Most potential for non-livestock injury in these structures occurs from exposure to falls from heights, particularly in the case of barns with lofts for hay storage. These are often poorly lighted and footing is questionable at best. This hazard has been significantly reduced in recent years more as a result of changing economics than a concerted effort to improve safety. Due to rising labor costs, and a lack of willing workers, many farmers have moved to the use of large bales, both round and square, to meet their hay storage needs. As such, the danger of falling from lofts diminishes and is illustrative of how changing practices lower injury potential in one area and creates new hazards. In this case, the chance of being crushed by shifting bales that may weigh up to three-quarters of a ton.

Other hazards associate with barns and livestock facilities include some of the same as found in sheds, falls from obstructions and debris, being struck by falling objects (hay) and being crushed by shifting materials, swinging doors and gates and by leaning objects.

Manure Storage Structures

In recent years, livestock production has shifted to confinement production systems. This results in larger numbers of animals occupying smaller areas, with a corresponding concentration of animal wastes. Liquid manure handling systems are now widely used. Many of these systems use belowground pits (in-ground concrete "tanks"), aboveground storage tanks, lagoons or

combinations of all three. Large amounts of manure concentrated and stored in these areas for long periods of time (typically 6 months or more), results in the potential of gasses being produced as normal biological activity decomposes the manure. Among these gases are carbon dioxide (CO_2), hydrogen sulfide (H_2S), ammonia (NH_3) and methane (CH_4). Carbon monoxide (CO) may also be present as a result of inefficient or faulty heating systems in the buildings.

In recent years 25 to 30 fatalities have been reported across the United States when workers entered manure pits and were overcome. These incidents often claim multiple victims when workers or family members attempt a rescue without proper tools or training. Extreme care must be taken when working with manure storage and handling facilities. Some of the hazards faced in manure pits include:

-- Toxic atmospheres
-- Oxygen deficient atmospheres
-- Entanglement in scrapers, pumps, agitators and other mechanical equipment.
-- Slips and falls resulting from slippery surfaces
-- Drowning in liquid manure
-- Electrocution (heightened by wet environment)
-- Respiratory problems created by dust and other air contaminants
-- Pathogens present in the waste (zoonosis)

Manure storage structures are high-risk areas and often unpredictable. Appropriate safety measures need to be taken when working in and around these structures.

Tripp et al. (1998) conducted a needs assessment of swine production facilities in Minnesota utilizing employees other than family members to determine the status of their efforts at providing a safe working environment and complying with regulations. They found that less than half of producers with less than 10 employees had planned safety programs. Their study reinforced the call for more study into specific injuries in an attempt to study specific mechanisms of injury in these facilities to develop better intervention methods.

Silos

Vertical or tower silos are some of the most visible structures on the farm. These may be oxy-limiting, or non-oxygen-limiting. Oxygen-limiting silos are commonly made of glass-lined steel and are capable of being sealed. They use an atmosphere low in oxygen and high in carbon dioxide to preserve the material inside. Non-oxygen-limiting silos are also known as conventional silos or stave silos. They are typically made of concrete staves and do not limit the oxygen levels in the silo. Silos store the crop by reducing oxygen within the silo and creating atmospheres that reduce spoilage of the stored material. Among the safety and health hazards associated with silos are:

-- Creation of oxygen deficient atmospheres
-- Potential for creation of toxic gases such as the oxides of nitrogen (NO, NO_2, N_2O_4), as well as high levels of carbon dioxide (CO_2) due to the fermentation of stored crops.

-- Fall hazards associated with walking on unstable surfaces.
-- Possibility of entanglement in machinery such as un-loaders.
-- Falls from the silo structure itself, its ladders and chutes.
-- Electrocution hazards.
-- Biological and respiratory hazards associated with dusts and molds from the plant material (farmers' lung) and from insects, rodents and snakes that may take up residence.

Silos also are susceptible to fires from spontaneous combustion of improperly stored plant material. This scenario also poses safety issues with responding emergency services, particularly, rural volunteer fire departments.

These structures are also an example where changing practices may reduce the injury potential. Recent moves to bunker silos and bags may help to reduce the number of injuries associated with silos.

Grain and Feed Bins and Pits

Grain bins are similar to silos except they are usually shorter, wider and made of galvanized steel. They are used to store small grains, and can be fitted with dryers to remove moisture from the grain. Grain pits are less common on the farm. A grain pit is a recess in the ground made of concrete, steel or both. They are covered with a metal grate that allows vehicles to drive over the top and dump grain through the grate into the pit. Grain is usually removed from the pit by an auger conveyor or a high-speed vertical bucket conveyor called a grain leg. Both of these types of structures create a number of specific hazards.

Bins create a number of hazards:

-- Grain within the bin can engulf and suffocate a worker.
-- Oxygen deficient atmospheres can be created as normal biological processes within the stored grain consume oxygen and release carbon dioxide. The greatest danger is when spoiled grain releases high levels of carbon dioxide.
-- Molds and dusts may be present which can cause health problems such as Grain Fever and Farmers Lung.
-- Toxic fumes may be present if pesticides are used to combat insects and rodents.
-- Augers, stirring devices and other mechanical equipment within the bin can entangle a worker.
-- Falls can occur from walking on unstable surfaces.
-- Falls from the bin structure.
-- Electrocution hazards
-- Oxygen deficient and toxic atmospheres can develop in grain that is burning caused by spontaneous combustion.

Grain pits or dump pits have many of the same hazards and also create some unique hazards. These include:

-- Grain within the pit can engulf and suffocate a worker.

-- Oxygen deficient atmospheres can be created by normal biological processes in the grain and from external sources such as vehicle exhausts and exhaust from dryers operating nearby.
-- Molds and dusts may be present which can cause health problems.
-- Fall hazards associated with walking on unstable surfaces.
-- Entanglement in machinery such as augers and elevators.
-- Falls into the pit from the surrounding ground surface.
-- Electrocution hazards

Bins and pits are structures that seem to have received more study than other agricultural structures. The research conducted covers a wide range of topics related to bin safety. A significant amount of work has been done to examine the extent of fatalities and injuries associated with grain structures (Kingman, Field and Maier, 1999; Freeman et al., 1996, Kelly and Field, 1996). From this work, we have a clearer idea of the extent of the injury problem associate with them.

Another significant work is Schwab et al. (1985) who investigated the forces acting on a person engulfed in grain using mannequins and provided much needed insight into the amount of force that is involved in an engulfment. They found that on mannequins buried to depths three feet over their heads, forces reached nearly three-quarters of a ton. This type of data provides information of designers interested in safety harnesses, for rescue personnel who can use the information for better planning rescues and for educators who can use the information to impress upon farmers and workers the dangers they face.

Work on developing devices to reduce the possibility of engulfment and provide tools for rescue teams has also been conducted. This work includes recent efforts at the University of Illinois in the development of safety harness systems to protect the entrants (Aherin, R.A., 2001) which shows promise, and the development of the Grain Rescue Tube to give rescue personnel a tool to use in partial engulfments (Carpenter and Bean, 1990).

Another research effort of interest includes Burroughs' (1999) examination of the perceptions of farmers, the safety practices they follow, and methods to reach farmers with grain safety information. Her work indicated that Illinois farmers questioned perceive engulfment (20%) and augers (22%) to be the greatest hazard they face. She also found that dust masks were the most commonly used safety device (58%) and that few farmers seemed willing to make investments in safety devices or even install them if provided. She also found that most farmers indicated they obtained their safety information from farm publications which supports findings from other researchers.

As mentioned earlier, adoption of safety devices is often an issue in agriculture. The most successful adoptions often involve devices that make the farmer's job easier. This is witnessed in the adoption of stairs on grain bins as well as commercially available devices that show the grain level within the structure. While these devices make the job safer, the success in adoption is often more a result of selling the convenience provided by the device. This needs to be exploited.

Other Structures

A number of other structures are present in agriculture and on farms. These include such things as feed hoppers, old well pits and cisterns, pesticide storage tanks, bulk milk tanks, molasses storage tanks, and many others. Feed hoppers are small grain bins designed to hold feed which often have sloped bottoms to ease removal of the material. For discussion of the hazards faced, refer to the section on grain bins. Old well pits and cisterns are still found on some farms. The hazards faced are primarily oxygen deficient atmospheres and drowning. As farms grow larger, pesticides are often handled in large volumes using a variety of stationary and portable tanks. The atmospheres inside these tanks tend to be toxic. It is important to understand the characteristics of the material inside the tank. Molasses is used to make feed more palatable for cattle. Large storage tanks are often used by cattle producers to store molasses. Biological processes within the tanks can produce toxic and/or oxygen deficient atmospheres similar to those faced in silos and manure pits. Many other examples of confined spaces can be found. It is important for the farmer and worker to be able to identify and analyze these structures in order to understand the dangers faced and utilize appropriate strategies for working in and around these spaces.

Summary

As discussed in the preceding pages, agriculture uses a wide variety of structures. Many of these structures pose significant safety and health risks. Farmers, workers, contractors, emergency personnel and others who may have contact with these structures need to thoroughly understand the nature of these structures and the hazards posed. While some research has been conducted, particularly in the case of grain handling structures, significant gaps exist in our understanding of these hazards in these structures and of our ability to provide appropriate and effective interventions. Farmers continue to be exempted from safety and health regulations and are inclined to continue to work to prevent additional regulations.

Recommendations

The following recommendations are offered as a starting point for the discussions that will follow at this conference. The author does not claim these recommendations are a comprehensive list, but rather a stimulus for discussion. Hopefully it will elicit many more ideas. Once these ideas have been created, prioritization can begin to give some focus to future research endeavors. One of the major considerations is to attempt to address some of these recommendations within the context of the efforts begun from Agriculture at Risk.

1. Additional research on current Agricultural injury data must be conducted to clarify the extent to which structures are involved, and to more thoroughly understand the mechanisms of the injuries caused by exposure to the hazard's within.
2. Additional studies to collect injury data to fill in the gaps in our knowledge of structures related injuries.
3. Meaningful evaluation of current intervention strategies should be undertaken. This research should be keyed to identifying the interventions that work, and more importantly, why they

work.
4. Research should be conducted to develop new safety devices, and to develop safer designs on structures. These devices should be "user friendly".
5. Manufacturers should be included in the discussion of safety and health issues related to structures to encourage them to take an active role in the education and promotion of safety in addition to their influence on engineering.
6. Efforts should be made to incorporate structures related safety issues into current and new safety education programs
7. Research suggests that many farmers receive their safety information from the farm press and media. These organizations should assume highly visible leadership roles in the safety education and promotion efforts. Safety and Health should be an integral part of their publications and/or broadcasts.
8. Serious discussion of the benefits of current and future exemptions should be undertaken by all stakeholders.

References

Aherin, R.A.. 2001. Personal Communication. January 30, 2001.

Becker, J.B. 2000. An analysis of Agricultural Accidents in Florida - 1992. National Agricultural Safety Database. Accessed via the internet, 1/20/2000 at www.cdc.gov/niosh/nasd/docs/as34001.html

Burroughs. J.E.. 1999. Grain Bin Safety. Unpublished Master's Thesis, Southern Illinois University Carbondale. Carbondale, IL.

Carpenter, T.G. & Bean, T.L.. 1990. The Grain Rescue Tube. Paper presented at the Grain Elevator and Processing Society Exchange '90. San Antonio, Texas. March 18-21, 1990.

Cyr, D.L. & Johnson, S.B.. 2001. Storage Building Safety. University of Maine Cooperative Extension Service Fact Sheet. National Agricultural Safety Database. Accessed 1/21/01 at www.cdc.gov/niosh/nasd/docs3/me97032.html.

Freeman, S.A., Kelley, K.W., Maier, D.E. & Field, W.E.. 1996. Review of Entrapments in Bulk Agricultural Materials Commercial Grain Facilities. Presentation at the 1996 International Meeting of the American Society of Agricultural Engineers. Paper No. 965029. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA

Gelberg, K.H., Struttman, T.W. & London, M.A.. 1999. A comparison of Agricultural Injuries between Young and Elderly: New York and Kentucky. Journal of Agriculture Safety and Health. 5(1)73-81.

Hard, D.L., Myers, J.R., Snyder, K.A., Casini, V.J., Morton, L.L., Cianfrocco, R & Fields, J.. 1999. Identifying Work-related Fatalities in the Agricultural Production Sector Using Two National Occupational Fatality Surveillance Systems, 1990-1995. Journal of Agriculture Safety

and Health. 5(2)155-169.

Kelly, K.W. & Field, W. E. 1996. Characteristics of Flowing Grain-related Entrapments and Suffocations with Emphasis on Grain Transport Vehicles. Journal of Agricultural Safety and Health. 2(3):143-156.

Kelsey, T. W.. 1994. The Agrarian Myth and Policy Responses to Farm Safety. American Journal of Public Health. 84(7):1171-1177.

Kingman, D.M., Field. W. & Maier, D.. 1999. Summary of Fatal Entrapments in On-Farm Grain Storage Bins - 1964-1998. Presentation at the 1999 International Meeting of the American Society of Agricultural Engineers. Paper No. 997041. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA

Marshfield Medical Research and Education Center, 1996. Fact Sheet, 1996 W Number 1 Agricultural Injury.. National Agricultural Safety Database. Accessed via the internet, 1/20/2000 at www.cdc.gov/niosh/nasd/docs3/wi79001.html.

Murphy, D.J., 1992. Safety and Health for Production Agriculture. St. Joseph, MI:American Society of Agricultural Engineers.

Murphy, D.J., Kiernan, N.E., Hard, D.L. & Lansittel, D.. 1998. The Pennsylvania Central Region Farm Safety Pilot Project: Part I - Rationale and Baseline Results. Journal Of Agriculture Safety and Health. 4(1): 25-41.

National Safety Council, 1999, Accident Facts, 1999 edition, Itasca. IL: author.

National Safety Council, 2000, Injury Facts, 2000 edition, Itasca. IL: author

NIOSH 1994. Worker Deaths in Confined Spaces: A summary of Surveillance Findings and Investigative Case Reports. U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Safety Research. DHHS (NIOSH) Publication No. 94-103.

Pahwa, P., Zasada, M., McDuffie, H.H., McNeil, G. & Dosman, J.. 1995. Results of a Survey on Farm Accidents in Saskatchewan. In Agricultural Health and Safety: Workplace, Environment, Sustainability. H.E. McDuffie, J.A. Doseman, K.M. Semchuk, S.A. Olenchock, A. Senthilselvan. Eds. New York: Lewis Publishers pp. 275-282.

Shireley L. A. & Gilmore, R. A.. 1995. A Statewide Surveillance Program of Agricultural Injuries and Illnesses - North Dakota. In Agricultural Health and Safety: Workplace, Environment, Sustainability. H.E. McDuffie, J.A. Doseman, K.M. Semchuk, S.A. Olenchock, A. Senthilselvan. Eds. New York: Lewis Publishers pp. 289-293

Schwab, C.V., Ross, I.J., Piercy, L.R., McKenzie, B.A.. 1985. Vertical pull and Immersion Velocity of Mannequins Trapped in Enveloping Grain Flow. . Presentation at the 1985

International Meeting of the American Society of Agricultural Engineers. Paper No. 852806. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA.

Tripp, R.S., Shutske, J.M., Olson, D.K. & Schermann, M.. 1998. Needs assessment of employers in swine production facilites regarding employee health and safety. Journal Of Agriculture Safety and Health. 4(4): 231-243.