Characteristics of Flowing Grain-related Entrapments and Suffocations with Emphasis on Grain Transport Vehicles

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Abstract

A study was undertaken to estimate the frequency, contributing factors, and characteristics associated with fatalities resulting from on-farm flowing grain entrapments, with special attention given to grain transport vehicles (GTVs). A total of 235 cases were identified, 39 of which involved some type of GTV.

Children, ages 2 to 16, were found to have the highest frequency of suffocation in flowing grain, accounting for 43% of all identified fatalities. Of the identified GTV incidents, 87% involved a child under 15 years of age. The average known age in the GTV cases was 11 years old and overall the average known age was 32. These events predominately occurred in the geographic region known as the "corn belt". Seventy-four percent of the GTV-related fatalities occurred during October and November when most of the corn in the Midwest is harvested. Few incidents were identified outside of the harvest period. It is clear that this type of entrapment is strongly related to the harvest and transport of shelled corn from the field to the farm. Shelled corn was involved in 112 of 142 cases overall and in 20 of the 23 GTV cases where the material was known. Recommendations for reducing the frequency of entrapments in GTVs are provided.

Keywords. **Safety, Entrapment, Flowing grain, Wagon.**

In 1978, Purdue University's Agricultural Safety and Health Program (ASHP) conducted a study to investigate on-farm entrapments and suffocations in flowing grain. This study was the first known formal attempt to estimate the frequency of these events and to determine the primary contributing factors through on-site epidemiological investigations. It was anticipated that the findings from this research would provide a better understanding of the problem and lead to recommendations that would be effective at reducing the frequency and severity of these incidences. A summary of this initial study's findings, regarding 59 separate cases of flowing grain-related entrapments and suffocations involving 61 individuals resulting in 38 fatalities, was reported in an unpublished ASAE technical paper in December 1979 (Field and Bailey, 1979). This paper also included specific design and safety education-related recommendations. The findings and recommendations generated by the study contributed to greater public awareness of the problem and helped encourage the introduction of design features, such as improved hazard warnings and greater use of inside bin ladders, which generally were not incorporated into grain handling equipment prior to that time. Findings from the

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study were also used to eventually develop more effective victim extrication techniques in cases of entrapment (Baker et al., 1982).

Fifteen years later, the ASHP staff decided to revisit the problem from a nationwide perspective. It was anticipated that a revised set of recommendations for future injury prevention strategies would be generated. A decision was made to give special attention to incidents involving grain transport vehicles (GTVs), primarily gravity-flow containers, due to the considerable media attention given to this particular type of entrapment, and to assist the ASAE PM-03/3, "Wagon Box, Forage Box, Manure Spreader, and Farm Wagon Subcommittee" in their deliberations to develop design standards that would reduce the potential of entrapments and suffocations in these vehicles.

Data were analyzed from 235 fatal farm work-related entrapments identified as having occurred in free-flowing agricultural materials between the years 1964 and 1994 in 23 states and one Canadian province. Of the 235 cases, 39 were identified as involving some type of GTV. We will focus on the findings associated with these 39 incidents and how they compare to other types of flowing grain suffocations, where helpful. The data presented reflect a "best picture" of a problem that is undoubtedly underestimated, due to the lack of comprehensive reporting and accurate classification of agricultural-related fatalities.

Literature Review

A review of agricultural safety and health literature published since the Field and Bailey study in 1979 revealed little that has been added to develop a better understanding of the problem of entrapments and suffocations in flowing grain, especially with respect to GTVs. The most notable exceptions are the work by Schwab et al. (1985), and a few farm injury studies in which entrapments and suffocations are summarized, such as Sheldon (1992) and Skromme (1986-1987).

Schwab et al. (1985) examined the vertical pull applied to a subject and the inflow velocity at which a subject can become engulfed during the unloading of a bin. Vertical forces ranging from 900 to 1700 N (200 to 380 lbf) were measured when a 183 cm (6 ft) tall mannequin was suspended waist deep. Vertical forces up to approximately 11 000 N (2,500 lbf) were measured when the mannequin was fully submerged in shelled corn. The forces that were experimentally determined indicate the difficulties associated with self-extrication once engulfed or extrication by rescuers using ropes and harnesses. The inflow velocity tests determined the time required to completely submerge a 1.83 m (6 ft) tall mannequin in shelled corn is approximately 30 s at a grain flow rate of 144 m^3/h (4,086 bu/h).

Sheldon (1992) analyzed fatal childhood injury data from Indiana and Wisconsin from 1970 through 1990. He identified 33 fatalities due to asphyxiation or suffocation and 27 of the 33 fatalities involved grain, feed, or other loose material. Suffocation by loose, flowing material accounted for 7.2% of all deaths over the 21-year period. Sheldon also reviewed a National Safety Council (NSC) survey of 4,500 farms in 31 states from 1972 through 1982, which included a total of 756 reported injuries to children in the age ranges of 1 to 4 and 5 to 14. The NSC study did not include any clearly identifiable cases of entrapments or suffocations in flowing grain.

A number of Extension publications and audio-visual presentations have also been prepared on the topic of entrapment and suffocation in flowing grain, such as "Beware of Flowing Grain Dangers" (Field, 1988), "Safe Storage & Handling of

Grain" (Aherin et al., 1986), "Suffocation Hazards in Grain Bins" (Loewer and Loewer, 1976), "Farm Accident Rescue" (Baker et al., 1982), "Preventing Entrapment and Suffocation Caused by the Unstable Surfaces of Stored Grain and Other Materials" (NIOSH, 1987), and "Safe Grain and Silage Handling" (NIOSH, 1995). Most stress the importance of staying out of structures and vehicles when grain is being loaded or unloaded, and making these facilities and equipment off-limits to children. No empirical data or actual case histories were derived from these sources.

Entrapments in Grain Transport Vehicles (GTVs)

When a gravity-flow container is emptied, the flow of grain forms a flow path shaped like an inverted cone directly over the outlet. The vertical column of flowing grain passes through the grain mass with essentially no inflow of grain from the surrounding grain mass. This type of flow is referred to as enveloping or funnel flow. The flow pattern of grain from a GTV is partially dependent upon the configuration of the vehicle. Design features such as size, shape, and location of opening, shape of container, and internal features such as side supports can influence flow characteristics. Figure 1 is a sketch of how this flow pattern might look in a gravity-flow side-dump grain wagon. The flow pattern shown in figure 1 is similar to that from any container that empties due to gravity.

To help visualize the danger associated with GTVs, consider the rate of grain tank discharge for modern combines and the rate at which GTVs can be unloaded. A modern combine can discharge a 7.4 m^3 (210 bu) grain tank in under two minutes. A child in the bottom of a GTV can be covered in a matter of seconds. A typical capacity of today's grain storage and handling systems is approximately 105 m^3/h or 1.75 m^3/min (3,000 bu/h or 50 bu/min); therefore, a 250 bu grain wagon can be unloaded in about 5 min. A small child could become engulfed in less than 20 s (Kelley, 1995) once the grain begins to flow.

Methods

Case Identification

Due to the lack of a uniform reporting mechanism for agricultural-related injuries and fatalities, it was determined that the collection of data would focus on

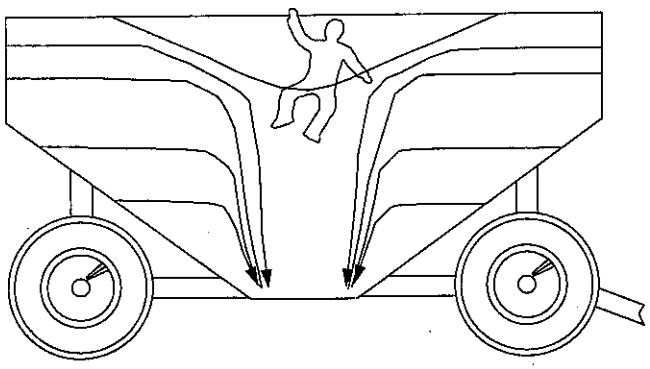

Figure 1–Flow patterns in a gravity-flow side-dump wagon.

entrapment fatalities, which could be more readily identified and documented than non-fatal incidents. However, the 62 non-fatal entrapment reports identified during the study clearly indicated that the occurrence of these events is not limited to fatalities. The original 38 fatalities identified by Field and Bailey (1979) between 1964 and 1978, along with information on an additional 26 cases gathered since 1979, were used as a starting point.

A review of the 2,653 fatality reports from 46 states that made up Purdue's Farm Fatality Database was undertaken in June 1993. These reports had been gathered from throughout the U.S. since 1970 and included only farm work-related fatalities. This review identified an additional 50 cases of fatal farm work-related grain entrapments. A significant portion of these cases originated from the work of Arnold Skromme, who gathered farm-related fatality reports from throughout the United States and published summaries for 1986 and 1987 (Skromme, 1986-1987).

Mailings were made to over 300 agricultural safety and health professionals to request their assistance in identifying cases of entrapment and suffocation in flowing grain and other agricultural materials. This resulted in reports, newspaper clippings, and case histories on over 110 cases. Several of the cases were already included in the Purdue database, but in many instances the newspaper clippings and case histories provided additional information on previously identified cases. Responses were also received from several Extension safety specialists who indicated no knowledge of specific incidents in their states over the past few years.

Over 50 published and unpublished farm injury reports were also reviewed from states and provinces that have conducted periodic studies or maintained on-going fatality reporting systems. This included reports from Arkansas, California, Colorado, Florida, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Montana, Nebraska, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Utah, Wisconsin, and the province of Ontario. To ensure that the "best possible picture" was reported, the Extension safety specialists/leaders in the major grain producing states of Iowa, Illinois, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio, and Wisconsin were contacted personally for any additional information on grain suffocation reports in their states.

Additional sources of data included the National Institute on Occupational Safety and Health (NIOSH), the National Safety Council (NSC), and Farm Safety 4 Just Kids. Each has shown an interest in the problem from regulatory and safety education perspectives. In total, over 300 cases (both fatal and non-fatal) that might have been caused by entrapment in flowing grain or other agricultural materials were identified.

Case Selection

The following criteria were used to select cases for further evaluation and safeguard against the inclusion of redundant citations:

- A grain storage facility, grain transport vehicle, or some type of granular or loose flowing agricultural material was involved.
- The accident type was identified as "entrapped/covered by grain/feed/loose material" or "asphyxiation inside a silo/bin/storage tank (containment structure)".
- Date and location of the incident available.

Each case was reviewed, and additional sources of information were sought, if a clear determination could not be made of the actual cause of death. Where possible, two sources were used to confirm that the incident involved flowing grain or other

agricultural material. Each case identified during the study was assigned an agent of injury from the Farm Accident Data Coding Sheet developed at Purdue University (Purschwitz, 1989). The coding sheet listed 72 possible agent of injury classifications consisting of agricultural-related machines, tools, and structures.

This review found that several cases originally identified as possible suffocations in flowing grain were actually caused by auger entanglements, falls from grain bins or GTVs, or involved other non-flowing grain-related agents. It was decided to restrict the study to flowing grain and other free-flowing, grain-related agricultural materials, therefore, approximately 20 cases involving sawdust, silage, corn cobs, straw, and fertilizer were eliminated during the case selection process. Incidents involving silage and silos, where the actual cause of death could not be determined, were also excluded to avoid the possible inclusion of asphyxiations by exposure to carbon dioxide (CO_2) or nitrogen dioxide (NO_2).

Analysis

A total of 235 cases of fatal farm work-related grain entrapments were determined to be relevant to the study and were selected for further investigation and summarization. The selected cases were analyzed as a whole and in three agent categories. The agent categories were defined as: 1) bin/silo, 2) GTV, and 3) other. The data were compared on the basis of the annual frequency, month of occurrence, weekday and time of occurrence, geographic distribution, age and sex of the subjects, and the material in which the fatal entrapment occurred.

Results and Discussion

The identified cases represent a census of known incidents. They are not, however, a population study of all fatal grain entrapments that occurred during the study period. It is believed that the findings associated with the incidents are representative of the problem.

Frequency

Figure 2 shows the distribution of the 235 identified cases over the 31 years from which data were gathered. The data shows an increase over the period with several

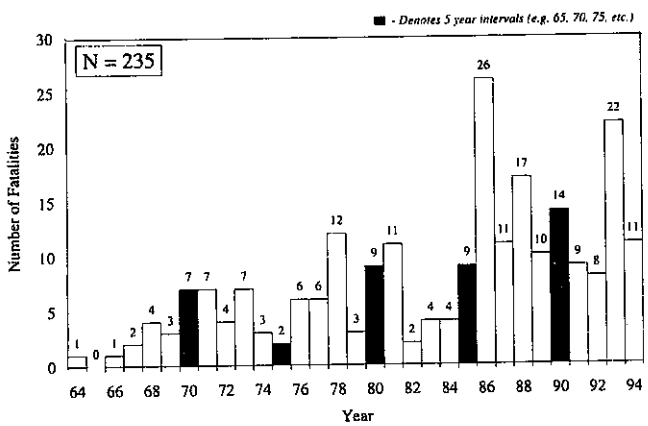

Figure 2–Annual distribution of all identified cases (1964-1994).

sharp peaks. Due to the lack of comprehensive reporting systems, figure 2 may also partially represent improved reporting during certain periods of the years studied. For example, the peak year of 26 fatalities was in 1986, when Arnold Skromme conducted his first nationwide search for farm-related fatalities. The second highest year (22) was in 1993, when the Purdue study of entrapments and suffocations was initiated.

Another factor that may correlate with the trends in annual frequency is the condition of the stored crop in a given year. In 1992, due to the combination of a bumper crop, a cold/wet fall, and a late harvest in parts of the Midwest, large amounts of corn were stored at higher than normal moisture contents causing long-term storage problems (Field, 1993). Many of the incidents reported in the fall of 1992 and during the spring of 1993 involved removal of crusted or out-of-condition corn from on-farm storage facilities.

Figure 3 shows the distribution of the identified wagon cases from 1964 through 1994 along with data on the annual shipments of gravity-flow wagon boxes (Bureau of the Census, 1971-1993). None of the 32 identified wagon cases are known to have involved an auger wagon, therefore, it is believed that the majority of the wagon cases occurred in some type of gravity-flow grain wagon. Due to the rapid increase in the number of gravity-flow wagon boxes manufactured and sold in the 1970s, it was expected that the frequency of wagon entrapment fatalities during the 1970s would have been greater than figure 3 indicates. However, this could not be substantiated by any of the reported data from several of the major grain producing states. The data does appear to suggest a substantial delay between the introduction of large numbers of GTVs such as gravity-flow wagons and the reporting of entrapments and fatalities.

As with the overall data set, figure 3 shows an increased frequency of cases since 1981, which may partially represent improved reporting in some years of the period studied. Again, the peak year was in 1986, when Arnold Skromme conducted his first nationwide search for farm-related fatalities. The 1990s showed a decrease in the frequency of GTV entrapment fatalities, which could be partially due to increased educational efforts in this area by various state extension safety programs

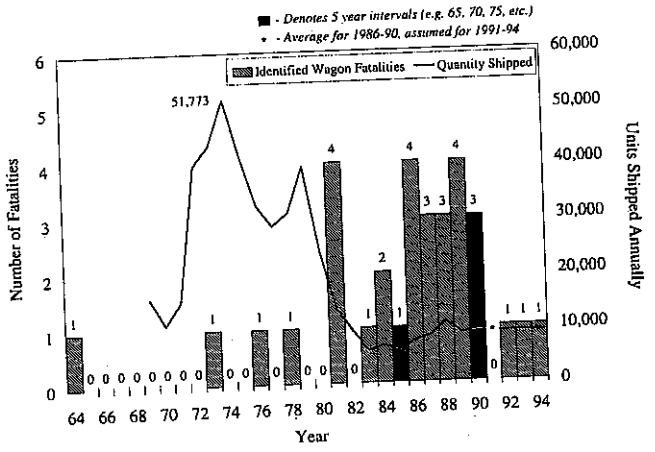

Figure 3–Annual distribution of identified wagon fatalities (1964-1994) vs. annual shipments of gravity-flow wagon boxes (1969-1994).

and independent organizations such as Farm Safety 4 Just Kids. Other variables that might have influenced the number of reported incidents included: fewer farmers/farms, introduction of larger capacity GTVs, and the introduction of warning labels on GTVs by some manufacturers.

Materials

The material involved was determined in 142 or 60% of the identified grain entrapment fatalities. The types of materials identified in the study were: shelled corn, soybeans, wheat, milo, feed (hog supplement and grain), ear corn, popcorn, grass seed, and oats. Of the 142 known material cases, 112 or 79% occurred in shelled corn. With respect to the GTV cases, the material was known in 23 incidents with 20 (87%) involving shelled corn.

Nearly 80% of on-farm storage is made up of shelled corn (NASS, 1994). Soybeans and wheat make up approximately 12% and 9% of on-farm storage, respectively. The high volume of shelled corn stored on-farm indicates a higher level of exposure to GTVs transporting shelled corn than other crops. Where soybeans and wheat may be transported directly to a commercial grain elevator, shelled corn is generally brought directly back to the farm from the field. Soybeans and wheat are also typically harvested during periods of lower humidity and at lower moisture contents, which will reduce the likelihood of spoilage. In addition, the fact that both soybeans and wheat flow at higher rates than shelled corn does not appear to have contributed to additional entrapments in those materials.

Geographic Distribution

The identified cases occurred in 23 states and one Canadian province. Although incidences of this type of farm work-related fatality appear widespread, it is reasonable to assume that the majority of grain suffocation cases occur in major grain producing regions. Table 1 lists the frequency of those cases, both overall and in GTVs, identified between 1985 and 1994 in the top 10 corn-for-grain producing states (NASS, 1985-1994). As expected, table 1 indicates a correlation between the production of shelled corn and the occurrence of grain entrapment incidences. Over the entire period studied (1964-1994), 89% of all identified incidents and 92% of GTV incidents occurred in the top 10 corn-for-grain producing states as listed in

Table 1. Cases involving shelled corn in the top 10 corn-for-grain producing states, 1985-1994

State	Average Production* (1,000 Bu.)	No. of Identified Fatalities in Corn	
		Total (n = 69)	GTV Cases (n = 22)
IA	1,470,170	14	5
IL	1,340,685	5	2
NE	925,760	5	2
IN	687,953	17	5
MN	652,660	9	1
OH	406,243	4	2
WI	319,100	9	3
MO	235,323	-†	-
SD	230,390	3	-
MI	228,953	3	2

* Source: NASS, 1985-1994.
† No cases were identified in the last 10 years.

table 1, which supports the previously mentioned assumption. Those 10 states are patterned with diagonal lines in figure 4, which shows the geographic distribution of all identified cases throughout the United States and Ontario.

Fairly comprehensive data were available from Kansas, Missouri, New York, and Texas, for example; but few grain-related suffocations were identified. The fact that Indiana, the site of this and an earlier grain suffocation study, reported the highest number of cases (51) during the study period further suggests that the total number of incidents could have been greater than was reported in the other major grain producing states, especially during the earlier years of the study period. An illustration of this was the low number of incidences identified in Illinois during the period studied. The actual number of cases that may have occurred could be greater by a factor of two or more. Support for this conclusion is based on the fact that Illinois ranks as the second largest producer of corn-for-grain in the United States, while only ranking fifth in the number of identified fatal grain entrapments (see table 1). Iowa and Nebraska, however, reported comparable numbers to that identified for Indiana (40 cases identified in each state), and were considered two of the more complete sources of fatality reports. They also rank as the first and third largest producers of corn-for-grain annually in the United States.

Agent of Injury

Table 2 shows the distribution of the identified cases by agent of injury. It is clear that the most significant agent of injury was the grain bin. Of the 235 cases, 159 or 68% were reported to have involved grain bins. Grain wagons (unspecified and gravity-flow) were the second most often identified agents, reported in 28 or 12% of the cases.

In the majority of GTV cases, it is believed that the victim was not the operator and that the victim was on top of the grain mass without supervision or without the operator's knowledge. However, a lack of detail in the available case information prevents verification of this belief.

Age Distribution

Figure 5 provides a distribution of all identified incidents based on the age of the victim. The victims' ages ranged from 2 to 86 years of age. There were 8 cases when

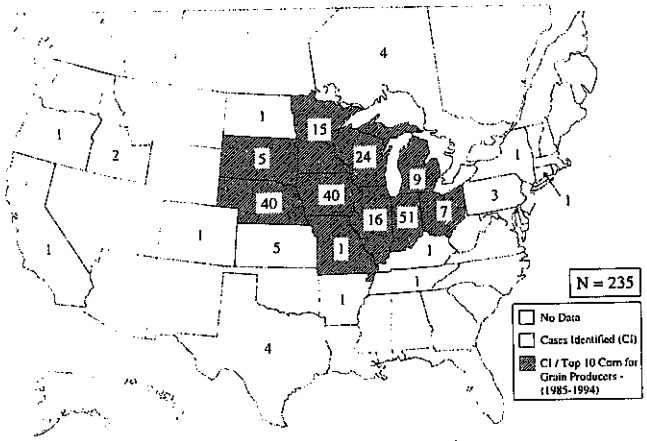

Figure 4–Geographic distribution.

Table 2. Summary of the identified grain entrapment fatalities by agent of injury

Agent of Injury	Cases per Agent	Percentage of Total*
Bin/Silo		
Grain bin	159	68%
Silo (unspecified)	10	4%
Auger (non-portable/in-bin)†	3	1%
Feed bin (ground feed)	1	-
	173	73%
GTV		
Grain wagon (unspecified)	17	7%
Grain wagon (gravity-flow)	11	5%
Wagon/cart (miscellaneous)	4	2%
Truck (unspecified)	4	2%
Truck (straight/grain/flatbed)	3	1%
	39	17%
Other		
Unknown‡	18	8%
Other	3	1%
Corn crib (ear corn)	1	-
Grain dryer	1	-
	23	9%
Total	235	99%

* Percentages are rounded to the nearest whole number. A dash (-) is used to designate those percentages less than 1%. Sum of the percentages does not equal 100% due to rounding.

† The agent "auger (non-portable/in-bin)" was used to classify those incidents where the victim was initially entangled in an auger, but subsequently became engulfed in the grain. The cause of death was ruled as suffocation due to entrapment in grain, not due to mechanical suffocation or injuries from entanglement in the auger.

‡ The available information was not descriptive enough to positively identify the agent of injury.

the age of the victim could not be determined from the available information. The average known age of the victims was 32. Children, ages 2 to 16, had the highest frequency of suffocation in flowing grain, accounting for 43% of the identified fatalities. Reports indicated that most were involved in non-work activities in the work place at the time of suffocation. Children age 11 were involved in more fatal

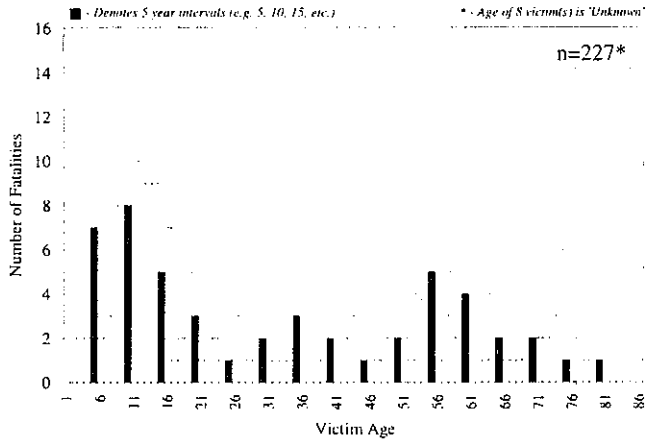

Figure 5–Distribution by age — all identified incidents.

grain entrapments than any other single age, accounting for 6% of the total number of deaths when the age of the victim was known. Data collected during this study also indicated that adults over the age of 40 may have an increased potential of being involved in a fatal grain entrapment, while adults between the ages of 17 and 39 exhibited a lower frequency than the previous two age groups.

Figure 6 shows the distribution of the ages involved in GTV incidents. This agent category primarily involved young children. Thirty-three (87%) of the 38 identified GTV incidents (age known) involved children under 15 years of age. There was one GTV incident where the victim's age could not be determined from the available information. The average known age in this agent category was 11 years of age.

Cases identified in the agent category "other" were distributed throughout the study's age range; however, 13 or 59% of the 22 cases of known age in the category involved children under 15 years of age. There was one incident where the age of the victim was not known. The average known age of the victims in the "other" category was 22.

Gender

The victim's gender was identified as male in 218 cases (94%) and as female in 13 cases (6%). In four cases, the gender of the victim could not be determined from the available information. With respect to GTVs, males were involved in 95% of the identified cases.

Seasonal Distribution

Figure 7 shows the distribution of all incidents where the date was known. The distribution of bin/silo cases appears to be relatively uniform throughout the year except for January, June, and December. These peaks generally parallel the movement of grain out of storage for marketing, which is consistent with Field and Bailey's (1979) findings that the predominant factor involved was the removal of out-of-condition grain from storage. The months with the lowest number of bin/silo incidents are generally considered to be the busiest periods for farmers, i.e., planting and harvesting.

Conversely, nearly all of the incidents involving GTVs took place during October and November when most of the corn in the Midwest is harvested. There were few

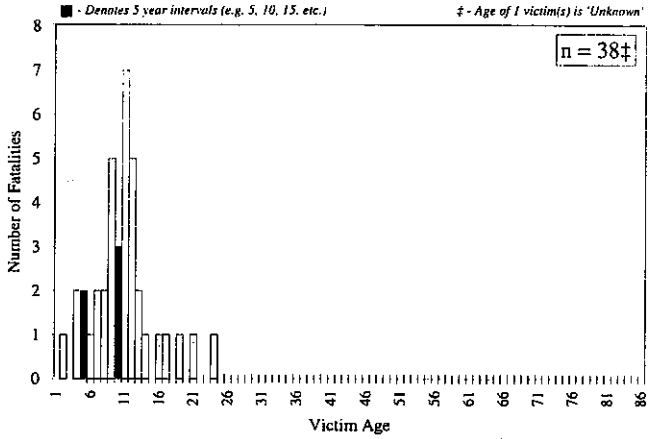

Figure 6–Distribution by age — GTV incidents.

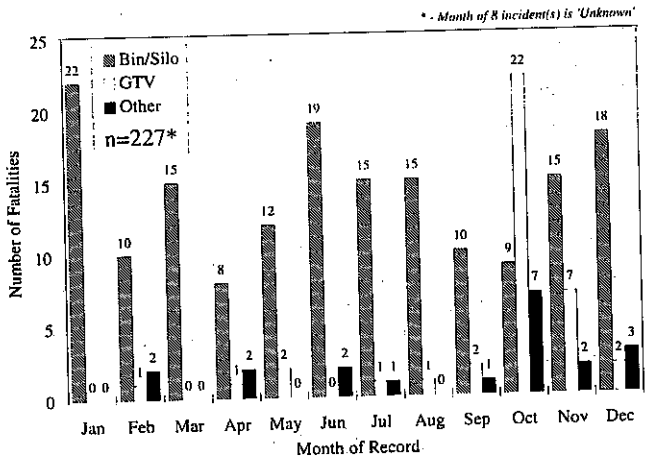

Figure 7–Month distribution.

incidents outside the harvest period. Fifty-eight percent of the incidents that occurred in October involved GTVs and 56% of all GTV incidents, where the date was known, occurred in October. It is clear that this type of incident is strongly related to the harvesting and transport of corn from the field to the farm, which was the material most frequently identified in entrapment cases.

Weekday Distribution

Figure 8 shows the frequency of the incidents by agent category with respect to the day of the week. The full date (month/day/year) of the incident was known in 189 of the 235 identified cases.

The bin/silo category had a peak on Tuesday and then the frequency tapered off through Saturday, with the majority of incidents concentrated between Tuesday and Thursday. The frequency of bin/silo incidents on Sunday (3) was dramatically less than any other day of the week. The peak day for the GTV category was Saturday

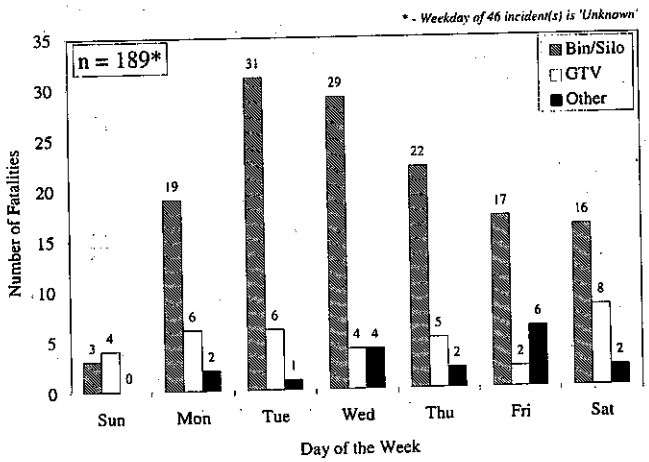

Figure 8–Weekday distribution.

representing 23% of the 35 GTV incidents where the full date was known. This was not completely unexpected as it was anticipated that GTV incidents might peak on the weekend (Saturday and Sunday) when younger children are more apt to be present. However, overall both the GTV and other agent categories appeared to be fairly evenly distributed throughout the entire week.

Time of Day

Data regarding the time of day was only available in 120 of the 235 identified cases. Of these 120 cases, 21 occurred in the morning, 79 occurred in the afternoon, and 20 occurred in the evening (after 6 p.m.). Cases involving GTVs were concentrated in the afternoon. The time of day was known in 25 of the 39 identified GTV cases. Of these 25 cases, 19 occurred in the afternoon, 6 occurred in the evening, but no cases were identified in the morning hours.

Conclusions

Based on the findings of this study the following conclusions were drawn concerning entrapments and suffocations in GTVs:

- Considering the large number of farm-related fatalities reported by the various sources reviewed, it is believed that fatal grain entrapments and suffocations in GTVs are extremely rare events. Suffocations in flowing grain account for less than 2% of all reported farm work-related fatalities. This observation is consistent with recent NSC farm fatality estimates and reports of entrapments and suffocations (NSC, 1995).
- There is no clear evidence to suggest that the frequency of suffocations in flowing grain, including GTVs, is increasing nationally. Increases in the number of reported and/or identified cases appear to reflect improved reporting mechanisms. Earlier, more dramatic increases during the 1960s and 1970s are believed to be related to the rapid expansion of on-farm grain storage. The poor condition of stored grain was also believed to be responsible for greater numbers of suffocations during some years.
- Eighty-seven percent of the identified GTV entrapment fatalities involved children, primarily boys, between ages 2 and 14, compared to only 24% in the bin/silo category. However, the bin/silo category involved 40 identified fatalities in the 2 to 14 age group, compared to 33 in the GTV category. As a percentage of the total number of identified cases per agent category, GTVs pose a much higher risk; however, based on the sheer number of identified incidents involving children, bin/silos appear to be a greater source of danger to children.
- GTV incidents were almost exclusively concentrated in the harvest months from September through December. Eighty-five percent of the identified GTV incidents took place during this period, while 56% took place in October alone.
- The distribution of bin/silo cases was concentrated in the middle of the week, with a peak on Tuesday. But the GTV cases were evenly distributed throughout the entire week, with a slight peak on Saturday, where there may have been a greater involvement of children in or an increased likelihood of children in the proximity of the grain handling activities.

Recommendations

- Even though entrapments and suffocations in flowing grain are relatively rare events, there exists a continuing need to include information on the hazards of flowing grain and other free-flowing materials in farm safety resources. Special attention should be given to visually demonstrating the speed at which the entrapment process takes place through the use of models showing flowing grain from bins and various types of GTVs.
- The collection of grain entrapment fatality data should be continued on a nationwide basis. With the improved data collection and storage systems that have become available in the last five years, it may be possible in the near future, perhaps two to five years, to determine whether the increased focus on the hazards of grain handling and the incorporation of safer designs into grain handling systems have actually reduced the annual frequency of such fatalities.
- Considering the number of entrapments and suffocations involving children, future farm safety programs should include a warning to parents and grandparents concerning the hazards of flowing grain, specifically the danger children face while riding or playing on grain in any type of GTV.
- Special attention should be given to the role of gender in the occurrence of entrapments and suffocations. Considering that 94% of the cases involved males, primarily boys, future grain handling safety programs should be specifically orientated towards young males.
- A warning decal, based upon the current standards, should be developed and submitted to industry for addition to all new GTVs. Also, a national program for adding such a decal to existing GTVs, similar to the successful "No-Rider" campaign for farm tractors, should be undertaken utilizing Vo-Ag, FFA, 4-H members, and other farm organizations.
- Warnings should also be incorporated into future operator's manuals and sales brochures associated with all types of GTVs, especially gravity-flow grain wagons, to further disseminate information on the hazards of flowing grain and raise the awareness of those operating the equipment.
- Based on the finding that children were often playing in GTVs without the presence or knowledge of the operator, it is recommended that efforts be made to hinder access into the grain box, especially for children. Recommended measures include the removal of any external ladders or placing them out of reach.
- To reduce the exposure to both children and adults, engineering solutions should be sought to the problems that lead individuals to enter a wagon box. These could include:
    - Addition of viewports in the wagon's sidewalls to aid in monitoring the level of grain
    - Removal of any flow obstructions (i.e., applying paint with graphite to the interior slopes of the wagon box and smoothing uneven surfaces where possible)
    - Means of agitating a bridged or crusted grain mass from outside the wagon box

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