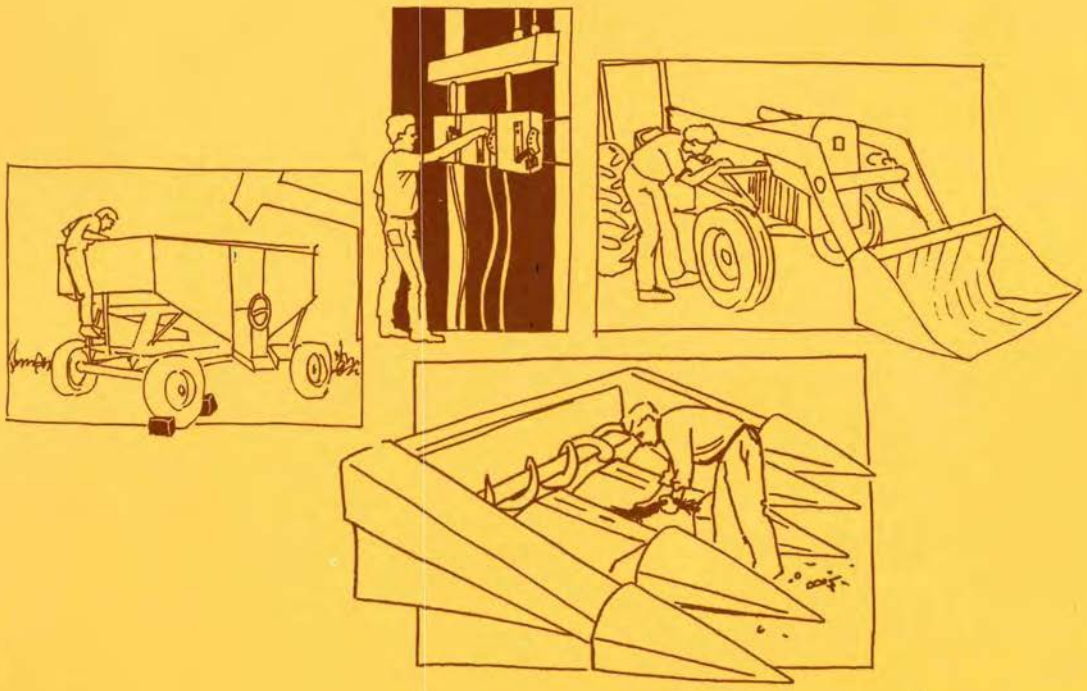
NIOSH

NATIONAL INSTITUTE FOR
OCCUPATIONAL SAFETY AND HEALTH

# Safe Grain and Silage Handling



# Safe Grain and Silage Handling

Compiled By

Karl Snyder
Thomas Bobick

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Divison of Safety Research

October 1995


The National Institute for Occupational Safety and Health (NIOSH) is part of the Centers for Disease Control and Prevention (CDC) within the Department of Health and Human Services. NIOSH is the federal Institute responsible for conducting research and making recommendations for the prevention of work-related injuries and illnesses.

## DISCLAIMER

Mention or implication of any company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

DHHS (NIOSH) Publication No. 95-109

# Safe Grain and Silage Handling
# Public Health Summary

## What are the hazards?

For the period 1985 through 1989, the top four leading causes of grain- and silage-handling deaths were:

1. suffocation under grain or silage or by gases in bins or silos
2. entanglements in augers on all types of machinery
3. falls from machinery, bins, and buildings
4. electrocutions from machinery contacting an overhead power line

Grain and silage harvesting, transportation, and storage involve machinery, bins, and silos, and a wide variety of work conditions that also result in many other hazards. Experienced farmers know that this type of work can be dangerous. Those who aren't as familiar with farming, or who haven't helped with a certain job, may not be aware of all of the risks.

## How do these hazards occur?

Farm workers usually do their jobs safely, but injuries can occur when work conditions suddenly change, when one's attention is distracted, or when there are hidden hazards. Examples of hidden hazards are a hillside too steep or too slippery for tractor stability, grain in a silo or bin that looks sturdy but falls away when walked on, hazardous gases that collect above grain or silage, or metal equipment that contacts overhead power lines if raised too high.

**How can these hazards be avoided?**

Many safe work practices have been developed and accepted by the agriculture industry. This booklet summarizes the work practices that apply to grain- and silage-handling tasks. These work practices range from recommendations for the size of fire extinguishers for combines, to maximum towing weights for tractors, to ways to clear poinsonous gas from silos. The booklet's goal is to remind workers of the hazards they are exposed to and suggest practical ways to prevent injuries.

The booklet is organized into five independent sections. Each of the five sections is meant to stand alone. Since some hazards are the same for several different jobs, some information is repeated in more than one section.

**How do I get more information?**

If you would like extra copies of this booklet, contact the National Institute for Occupational Safety and Health (NIOSH) at the number listed below. If you have questions about safety practices or about obtaining and installing safety equipment, contact your equipment dealer or Cooperative Extension Service safety specialist. For farm-related safety and health information that is not covered in this booklet, contact your Cooperative Extension Service safety specialist or NIOSH.

**1-800-35-NIOSH**
**(800-356-4674)**

## About This Booklet . . .

*"When tillage begins, other arts follow.*
*The farmers therefore are the founders of human civilization."*
*– Daniel Webster, 1840*
*American statesman, orator*

Grain-handling machinery is the second largest cause of farm machinery-related deaths and also causes many severe disfiguring injuries and amputations. Many grain-handling hazards can be avoided. The goal of this booklet is to point out these hazards and suggest practical ways to prevent injury. These suggestions were gathered from agricultural engineers and safety experts throughout the world, but primarily from the United States and Canada.

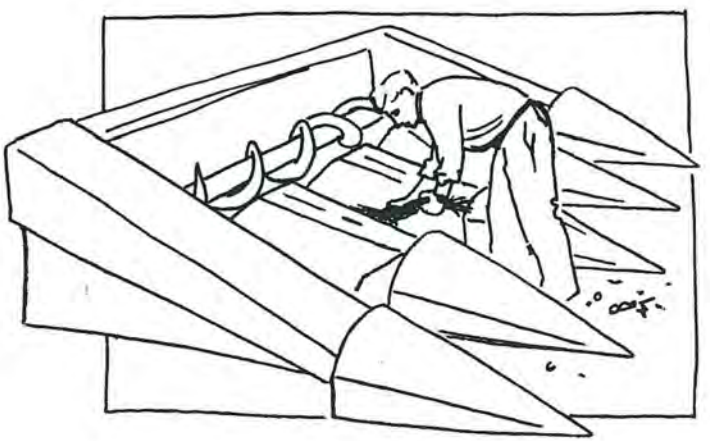
This guide is organized into five separate sections: harvesting, transportation, storage, conveying, and processing. Each section discusses the hazards for one of these five grain- or silage-handling activities. Since these sections are meant to stand alone, some information is discussed in more than one section.

This booklet may recommend the use of safety equipment that your machinery does not have. If you have any questions about safety practices, or about obtaining or installing safety equipment, contact your local equipment dealer or Cooperative Extension Service safety specialist. Either of these resources can help you make your farm a safer place to work.

The National Institute for Occupational Safety and Health (NIOSH) encourages the photocopying and distribution of part or all of this booklet to all those involved with grain- or silage-handling activities.

# Contents

# section 1
# HARVESTING

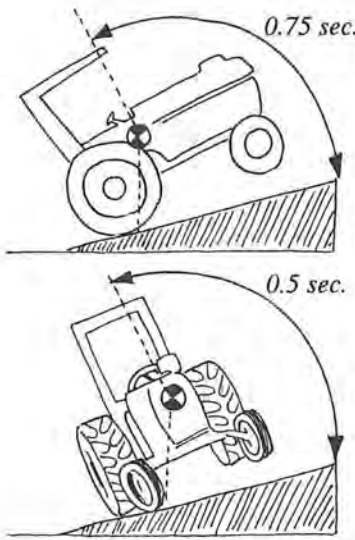


*"Farming looks mighty easy when your plow is a pencil, and you're a thousand miles from the cornfield."*

*– Dwight D. Eisenhower, 1956*
*34th U.S. President*

Grain and silage harvesting have many hazards. Harvesting is often done in a short amount of time, requires the operator's attention in several areas, and uses machinery that has many moving parts, some of which are difficult to shield. The risk of injury during harvesting can be greatly reduced, however, by being aware of the hazards and following basic safety practices.

This section is the first part of a five-part handbook on grain- and silage-handling hazards. Each of the five sections of this handbook is meant to stand alone, so some hazards will be discussed in more than one section. If you have already read one of the other sections of this handbook, some of the material in this section may be a review for you.



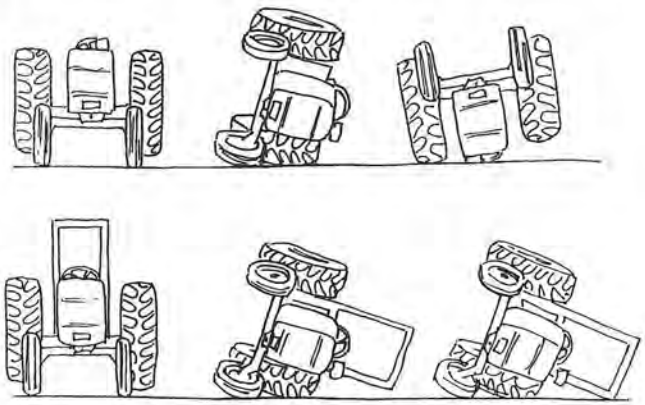

*1-1. A tractor can reach the point at which it will continue to roll and not fall back on its wheels in 0.75 seconds for rear overturns and in 0.5 seconds for side overturns. In many cases, you cannot react quickly enough to stop the overturn or jump to safety.*

## POWER UNIT SAFETY

Tractor rollovers are the largest single cause of agricultural machinery-related deaths. Why are rollovers so serious? Rollovers can occur so quickly that you cannot react in time to jump off the tractor or get out of the way. Rearward rollovers can occur in 1.5 seconds and rollovers to the side can occur in 0.75 seconds. The point at which the tractor will continue to roll and not fall back on its wheels (Figure 1-1), can be reached in 0.75 seconds for rear rollovers and 0.5 seconds for side rollovers. A person needs 0.3 to 1 second or more to recognize and respond to an unexpected event, depending upon the person, what that person is doing, and the distance the person has to move to respond. In many rollover circumstances, then, you simply could not react quickly enough to avoid injury after you realized that the machine had started to roll. The ways to prevent injury from a rollover are to prevent the roll from occurring and to protect yourself from being crushed if a roll should occur.

## 1-2 Roll-Over Protective Structures (ROPS)

Safe practices can reduce the chance of a rollover but not completely eliminate it. Roll-over protective structures (ROPS) can greatly reduce your chances of being killed if an overturn does occur. ROPS are designed to limit most rollovers to 90° and prevent operator deaths for rolls greater than 90° (Figure 1-2). These designs assume that the operator stays in the seat. To make sure you stay in the seat, you should always wear a seatbelt on machinery equipped with a ROPS. You shouldn't use a seatbelt on equipment without a ROPS, since staying in the seat on such equipment could increase your chances of injury.



*1-2. ROPS are designed to limit overturns to 90°, and prevent operator deaths for rolls greater than 90°.*

Although it is a good safety practice to use ROPS wherever possible, many farmers have an older tractor that does not have a ROPS. If you have a tractor without a ROPS, you can decrease your chance of being injured by using that tractor for jobs where a rollover is less likely to occur. Examples of such jobs would be stationary power take-off (PTO) use, pulling light loads, and working at lower speeds on flat, firm terrain.

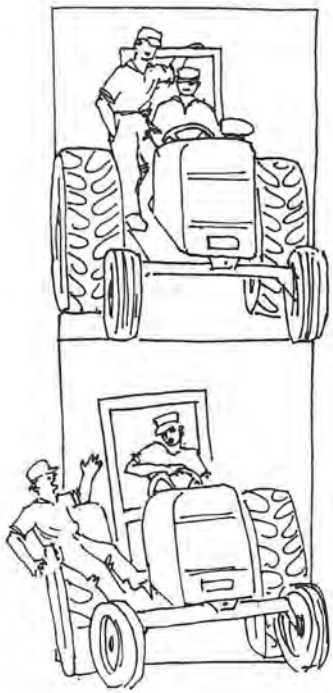
You can greatly increase your safety if you equip all of your tractors with a ROPS. Be sure that the ROPS has passed the standards of one of the following organizations: the American Society of Agricultural Engineers (ASAE), the Society of Automotive Engineers (SAE), or the Occupational Safety and Health Administration (OSHA). Look for a sticker or tag stating the ROPS has been approved by one of these organizations.

### Tractor Wheel Spacing

Tractor wheels should be adjusted to the widest spacing that can be used for each job. The wider the tread width, the less the chance of a sideways overturn.

## Extra Riders

The only person who should be riding a tractor or self-propelled harvesting unit is the operator, unless the equipment manufacturer has provided a second seat. Extra riders can be thrown off or fall from the machine and be run over, or they can interfere with proper operation of the machine (Figure 1-3).



*1-3. Extra riders DO fall from equipment, often in front of the tires or a trailed implement. The driver can rarely react in time to avoid crushing this person.*

## Matching Power and Load

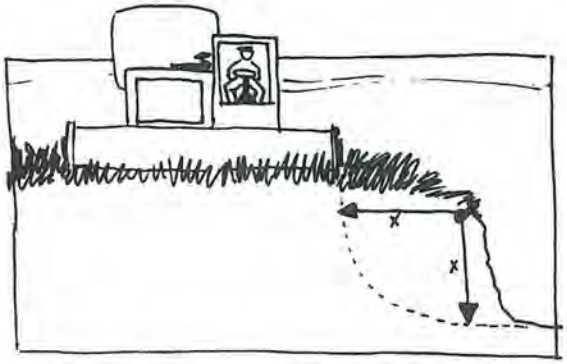
The tractor used to pull a harvester and wagon should be large enough to control the load. A tractor that is too small may not have sufficient braking power, weight, or traction to slow heavy loads or control them when going down or across a hill. Loss of traction can lead to an overturn.

Harvester and wagon combinations can cause rollovers if sharp turns are made when going downhill or at highway speeds, especially if the wagon is loaded. It is easy to forget that when a sharp turn is made, the force from the trailing equipment will try to jackknife and roll the tractor.

The individual brakes on tractors and self-propelled harvesters are good for providing control at slow speeds in soft or slippery conditions. These brakes should always be locked together, however, when traveling at highway speeds. Applying an individual brake at higher speeds can jackknife the equipment and lead to an overturn.

Another cause of upsets is tire blowout. Make sure that your tractor and wagon tires don't have deep cuts or cracks that could lead to a blowout and loss of control.

Stumps, rocks, ditches, or holes in fields are often forgotten as rollover hazards. It is easy to pay attention to the harvesting behind you and forget to watch for one of these dangers in front of you. One way to remember these hazards is to mark the field with tall painted stakes or flags when the crop is small and the



*1-4. Always leave plenty of room when turning or driving near a bank edge. Try to keep the distance from the tires to the bank edge equal to the ditch depth.*

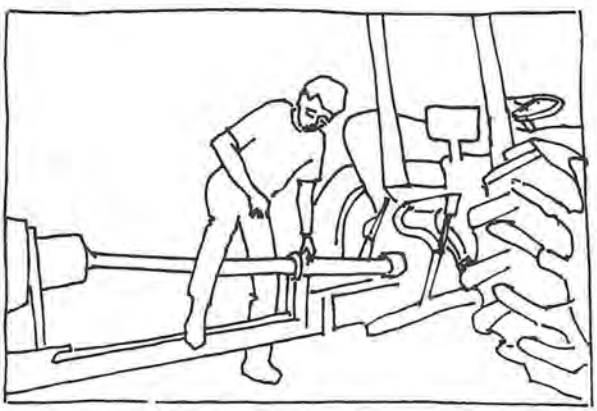
hazards can be easily seen. Banks of ditches or streams are also common overturn sites. Banks that were stable at planting may have eroded or may not be able to support the weight of harvesting equipment. Always leave plenty of room when turning or driving near a bank edge. The distance from the tires to the bank edge should equal the ditch depth (Figure 1-4).

**Power Take-Offs and Drivelines**

Although much has been published about the safe practices that should be followed when working around PTOs and drivelines, amputations and other severe injuries still occur. The way to prevent injury from PTO shafts and drivelines is to avoid contact and prevent entanglement if contact should occur. Although it is common sense to avoid contact with a driveline, injuries still occur when people step across or reach over or under a PTO shaft or driveline (Figure 1-5).

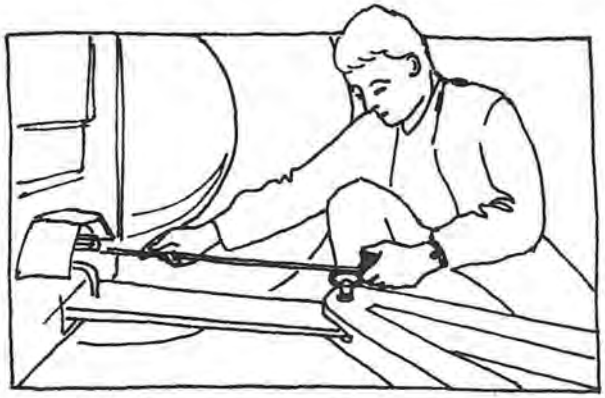
**Shielding**

PTO shafts and implement input drivelines should be shielded. The irregular shapes of the shafts and flexible joints grab loose clothing and hair very easily. Shields that were designed to rotate separately from the shaft that is inside should do so easily. This condition should only be checked, of course, with the shaft stopped.



*1-5. Never reach or step across an operating driveline, even if it is shielded.*

Rotating shields should be smooth and free from cracks or sharp edges that could entangle clothing, hair, or body parts.



*1-6. Check the owner's manual for the correct hitching height and distance when using PTO-powered equipment. An incorrect distance can cause the drive shaft to separate or fail.*

### Clothing

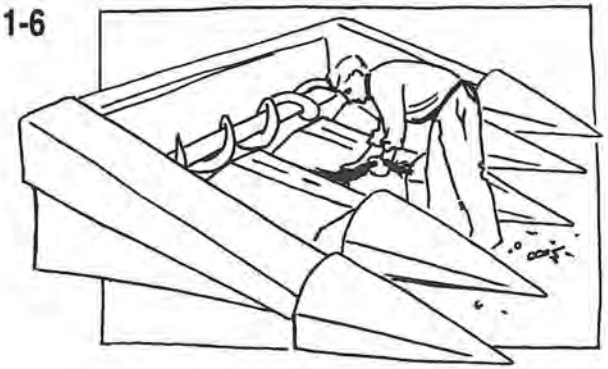
The clothing worn while working around PTO shafts, and other equipment, can also help to prevent entanglement. Work clothing should be well-fitting and zippered or buttoned, not open. Frayed clothes, jackets and sweatshirts with drawstrings, and boots or shoes with long shoelaces should be avoided. A shoelace or loose string, thread, flap of cloth, or the corner of a jacket can become entangled very easily.

### Hitching Height and Distance

It is also important to use the correct hitching height and distance for a PTO-driven implement. An improper hitching position can cause the drive shaft to fail or separate. When a PTO shaft fails or separates, the loose or broken ends can whip around violently and may cause severe injuries. Check the owner's manual for the proper hitching position (Figure 1-6). When using stationary PTO-driven implements, leave the implement hitched to the tractor so that the hitching distance doesn't change.

## HARVESTING UNIT SAFETY

Combines were the third largest cause of agricultural machine-related fatalities for the period 1980 to 1985. Combines are also involved in about twice as many injuries per 1,000 machines as tractors, yet are used fewer hours per year.



*1-7. Never try to clear a clogged harvester with the machine running. If the clog clears unexpectedly, you can be pulled into the machine before you can let go.*

## Harvester Servicing

About 50 percent of the reportable injuries from combines occur while cleaning, repairing, or adjusting the machine. Before performing any service, lower the header to the ground, place the machine in park or neutral, set the brake, stop the engine, and take the key with you. The owner's manual will specify those few operations that must be performed with the engine and machinery running or the header raised.

Never try to clear a clogged harvester with the machine running. If the clogged material clears, you can be pulled into the machine before you can react to let go or pull back (Figure 1-7). For example, corn is pulled through combine snapping rolls at more than 12 feet per second. If you are 3 feet from the rolls, your hand will be caught in 0.25 seconds. A person needs between 0.3 and 1 second or more to recognize and respond to an unexpected event. You cannot physically react in time; you will be caught! Stop the engine before clearing a clog to avoid this hazard.

Make sure harvester headers can't come down before getting under them (Figure 1-8). Use the manufacturer's hydraulic cylinder safety stops, if they were provided. If you have to use jacks, place them on firm, level surfaces, but use solid blocks to hold the machine when it is in position. Don't rely on jacks or other hydraulics for support; these can slip or develop leaks and you may be crushed.

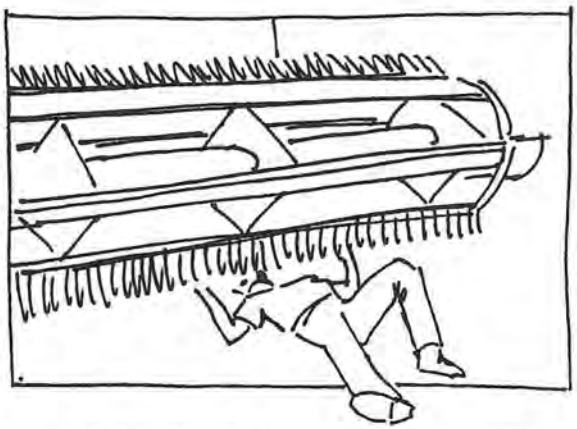
Check for the rotation of forage harvester knives before opening access doors. The knives can rotate for a long time after the engine power is stopped. Even though the knives may rotate for a long time, let them stop on their own. Trying to stop the knives with a piece of wood or metal can damage the machine, draw you into the knives, or injure you with flying pieces.

Always follow the manufacturer's recommendations when sharpening forage harvester knives, or when replacing knives, forage blower blades, or com-

bine cylinder bars. Be sure to torque the knife, blade, or bar attachment bolts to specifications. A loose bolt, nut, or part can become a lethal projectile.

**Road Safety**

Some harvester injuries are caused by collisions with other vehicles. Before traveling on the road, adjust hitches, fold unloading augers, or remove headers to make the machine as narrow as possible. Try to alert motorists as far in advance as possible by keeping bright, reflective Slow Moving Vehicle (SMV) symbols on all harvesters, tractors, and wagons. Use warning lights when possible. Signal all turns with lights or hand motions.



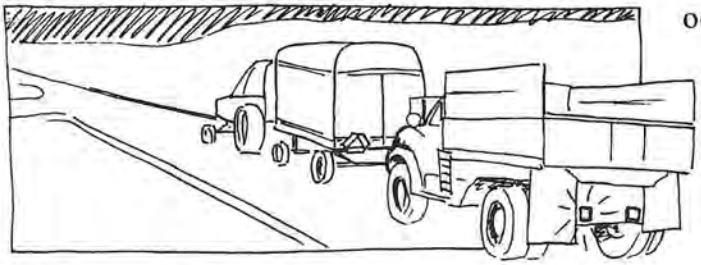
*1-8. Make sure that harvester headers can't come down before working under them. Use the manufacturer's hydraulic cylinder safety stops, if they were provided. If you cannot use safety stops, hold the header in place with solid blocks. Don't rely on jacks or hydraulics for support; if these slip or develop leaks you can be crushed.*

To allow traffic to pass, wait for a safe place, then pull off onto the shoulder and stop. Don't drive on the shoulder. The shoulder may be rough or have other handling hazards that could lead to an overturn. If your vehicle does start to tip into the shoulder, steering down into the ditch may prevent a complete overturn (Figure 1-9).

When going downhill, leave the transmission in a mid-range or low gear. Don't take the chance of losing control by shifting to neutral or leaving the machine in a high gear.

*1-9. Pull onto the shoulder and stop to let traffic pass. Don't drive on the shoulder; it may contain holes or other hazards that can cause overturns. If your equipment does start to tip into the shoulder, steering down into the ditch may prevent a complete overturn.*

Consider having an escort vehicle follow to help alert motorists (Figure 1-10). This is especially important if left turns have to be made. Collisions can



*1-10. Since most wagons don't have turn signals, consider using an escort vehicle to help alert other drivers. Collisions occur when machinery starting a left turn is hit by a car passing from behind.*

occur when machinery starting a left turn is hit by a car passing from behind.

**Harvester Stability**

Harvester stability is very dependent upon the header and grain tank. Heavy headers can tip the combine to the front. Keep the header as close to the ground as possible when traveling on or off the road.

The weight of the crop in the grain storage tank raises the harvester's center of gravity (Figure 1-11). Raising the center of gravity makes the machine easier to tip. Avoid traveling at highway speeds with a full grain tank and reduce your travel speed for all turns, on or off the road. Don't extend the tank height beyond that recommended by the manufacturer. Extending the tank too much can make the harvester top-heavy and prone to an overturn and could possibly damage the combine's frame.

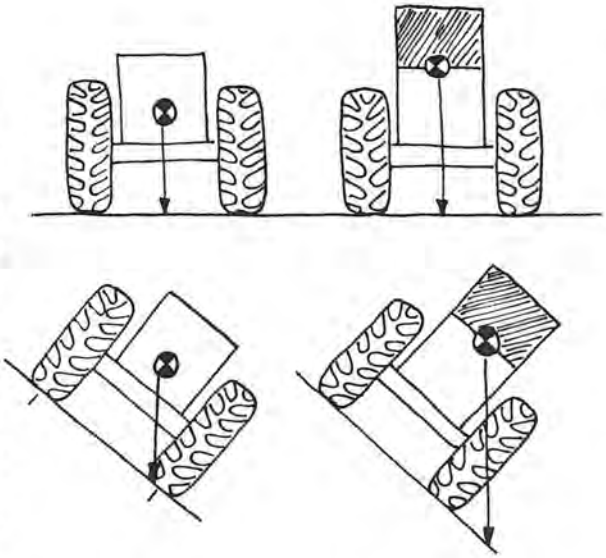
Make wide turns on slopes, especially when turning uphill. Tight turns can result in slipping, loss of control, and a rollover.

**Falls**

In some parts of the country, falls cause about 50 percent of the injuries due to machinery. A fall from a combine can be as much as 14 feet, and may result in a serious injury. Performing preventive maintenance in the off-season when you aren't in a hurry will help you reduce your chance of falling. If you must service machinery in the field, take time to clean the crop dust and debris from the steps and platforms you will stand on while working, and wear shoes with a solid, slip-resistant tread. Good traction will reduce your chance of slipping and falling.

## Fires

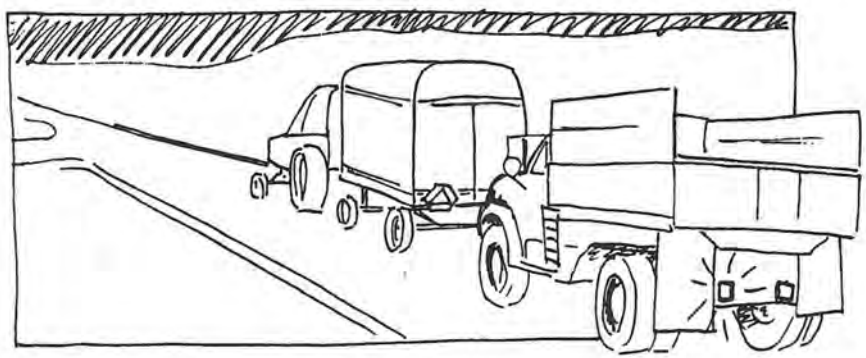
Harvesters can be fire hazards. Chaff and other bits of plant material can be ignited by engine components or from the heat of failing bearings or slipping belts. Fire hazards can be reduced by keeping belts tight, frequently removing dust and chaff buildup, and checking bearings regularly. It is also a good practice to have a multipurpose (A-B-C) fire extinguisher (5-pound minimum, 10-pound is better) on all tractors or self-propelled machines. Also consider carrying a 2 1/2- or 5-gallon pressurized or pump, type A fire extinguisher on combines. These extinguishers are better than type A-B-C extinguishers on type A fires (chaff and plant material) in windy conditions.



*1-11. The weight of the crop in the grain-storage tank raises the harvester's center of gravity, the average position of the harvester's weight. Extending the tank height above that recommended by the manufacturer can make the harvester top-heavy and prone to an overturn. If the center of gravity of a non-moving vehicle is between the wheels, the vehicle is stable. If the center of gravity is outside the wheels, the vehicle will overturn. The stability of moving vehicles is more difficult to predict, but keeping the center of gravity low will reduce the chance of an upset.*

Fires can also be caused by the exhaust systems of cars or trucks, especially gasoline-fueled ones. Gasoline-fueled vehicles may have catalytic converters that will glow red hot under normal use. Straw or stubble that comes in contact with a hot catalytic converter can easily catch fire. The risk of field fires can be reduced by keeping trucks and cars out of the field, or by cutting the crop very short in the loading areas and haul roads.

# section 2
# TRANSPORTATION

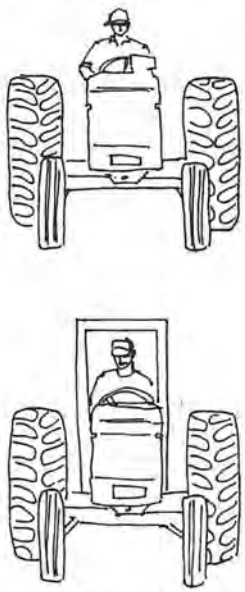


*"The farmer is the only [worker] in our economy who buys everything at retail, sells everything at wholesale, and pays the freight both ways."*

*– John F. Kennedy, 1960*
*35th U.S. President*

Grain- and silage-handling safety does not end with the harvest. Transportation, storage, and on-farm processing of grain and silage all have associated hazards. This section will concentrate on hazards and safe practices you should use while transporting grain and silage.

Grain transportation on the farm and from the farm to storage or sale varies greatly across the United States. The equipment used to move grain varies from farm tractors pulling gravity wagons to semitrailer trucks. This handbook will suggest some safety practices to observe while towing grain or silage wagons with a farm tractor, pickup truck, or grain truck. Remember that truck operation and regulations for towing farm wagons with trucks are covered by your state's department of transportation.



*2-1. Choose a tractor with a ROPS and wear a seat belt when pulling grain or silage wagons. Doubling your speed increases the possibility of an overturn by about four times.*

This section is the second part of a five-part handbook on grain- and silage-handling hazards. Each of the five sections of this handbook is meant to stand alone, so some hazards will be discussed in more than one section. If you have already read one of the other sections of this handbook, some of the material in this section may be a review for you.

## Power Unit Safety

The main safety considerations of grain and silage transportation are maintaining stability and control of the truck or tractor and wagon and avoiding other traffic.

Choose a truck or tractor that is large enough to control the loaded wagon. The towing vehicle must have sufficient weight and traction to be able to slow the wagon and control it through turns. Reduce your travel speed and use extra caution if the wagon weighs more than the vehicle towing it. Don't pull wagons that are more than twice as heavy as the towing vehicle, unless the wagon has its own brakes.

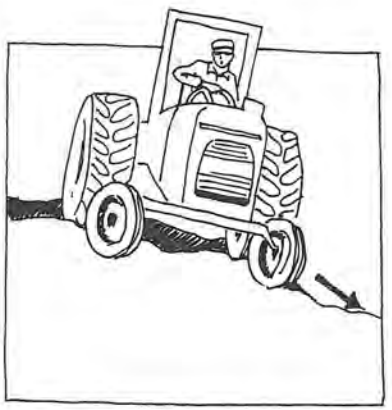
Slow down gradually if the wagon starts to fishtail,

weave, or bounce. Always reduce your speed for turns. Doubling your forward speed increases your chance of an overturn by about four times. Rolling the load can roll the vehicle pulling it.

If you are using a tractor to pull grain wagons, choose a tractor with a roll-over protective structure (ROPS) and wear your seat belt (Figure 2-1). If a roll or a collision does occur, you want the most protection possible. One cause of collisions and rolls is a tire blowout. Make sure that your tractor tires don't have deep cuts or cracks that could lead to a blowout and loss of control.

Remember to lock your tractor's individual wheel brakes together for road travel. Applying one brake too strongly can swing the tractor sideways, causing it to be rolled by the wagon. The tractor can also be forced into a spin with the brakes locked together if the brakes are not adjusted correctly. The owner's manual or your tractor dealer should be able to help you adjust the brakes to apply an equal amount of braking force when the brakes are locked together.

Sharp turns can also result in an overturn, especially if the wagon is loaded. When a sharp turn is made, the trailed equipment will try to continue in a straight line, which can jackknife and roll the tractor.



*2-2. Pull onto the shoulder and stop to let traffic pass. Don't drive on the shoulder; it may contain holes or other hazards that can cause overturns. If your equipment does start to tip into the shoulder, steering down into the ditch may prevent a complete overturn.*

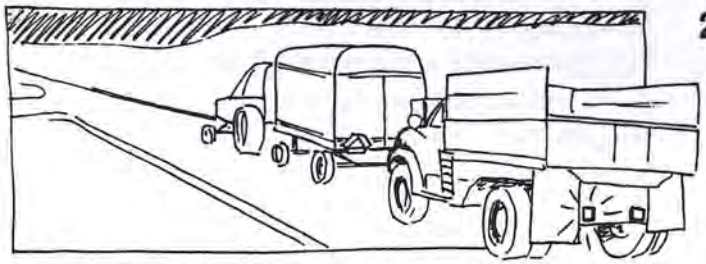
**Road Safety**

Try to alert motorists as far in advance as possible by keeping bright, reflective Slow Moving Vehicle (SMV) symbols on all tractors and wagons. Use warning lights when possible. Signal all turns with lights or hand motions.

To allow traffic to pass, pull off onto the shoulder and stop. Don't drive on the shoulder. The shoulder may be rough or have other handling hazards that could lead to an overturn. If your vehicle does start to tip into the shoulder, steering down into the ditch may prevent a complete overturn (Figure 2-2).

Shift to a lower gear before going downhill. Don't take the chance of losing control by

shifting to neutral or leaving the tractor or harvester in a high gear. A good rule of thumb is to go downhill in the same gear, or a lower gear, as you would use to go uphill.



*2-3. Since most wagons don't have turn signals, consider using an escort vehicle to help alert other drivers. Collisions occur when machinery starting a left turn is hit by a car passing from behind.*

Consider having an escort vehicle follow to help alert motorists. This is especially important if left-hand turns have to be made. Collisions can occur when machinery starting a left turn is hit by a car passing from behind (Figure 2-3).

## Wagon Safety

Loaded grain wagons will often weigh more than the tractor or pickup truck pulling them. If a heavy wagon has a tire or running gear failure, you may not be able to control the wagon with your truck or tractor, resulting in a collision or overturn. Proper adjustment and maintenance of the wagon's steering components will reduce fishtailing or weaving and the chance of component failure. Never exceed the maximum load recommended for the wagon's running gear or the tires. Use the proper tires for the running gear. As mentioned before, tires with deep cuts or cracks are blowout hazards and should be replaced.

*2-4. Secure all hitch pins with locking pins or clips. Consider using safety chains for road travel. Don't take the chance that the load could become unhitched.*

If you are towing a wagon with a pickup or other farm truck, do not exceed the manufacturer's recommended towing speed for the wagon or the tires. Reduce your travel speed and use extra caution if the wagon weighs more than the truck.

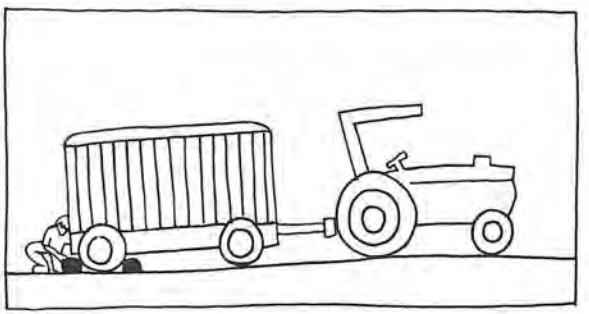
Locking pins should be used to secure the hitch pins for all wagons (Figure 2-4). Don't take the chance that the load could become unhitched.

Safety chains are also a good idea for road transport. These chains will allow you to maintain some control if the wagon should come unhitched.

Consider purchasing larger grain wagons equipped with brakes, especially wagons that will weigh more than the towing vehicle when loaded. Wagon brakes put the braking power for the load where the traction is, under the load. Also consider installing lighting packages on your grain wagons, particularly wagons that obstruct the lights on the pulling vehicle. Newer tractors have outlets for wagon lighting packages as standard equipment.

### Hitching Wagons

The task of hitching wagons is often overlooked as a source of severe injuries and deaths. The main hazard of hitching is being caught between the tractor or truck and the wagon. Avoid moving the tractor when there is a helper between it and the wagon. Back the tractor past the hitch point with your helper at a safe distance, then inch forward, away from the wagon, to align the hitch holes. With this method, if the clutch grabs or something else should go wrong, the tractor will move away from your helper. A sliding wagon tongue can help to speed hitching and reduce hitching hazards, since exact alignment of the hitch holes can be done with the tongue rather than the tractor.

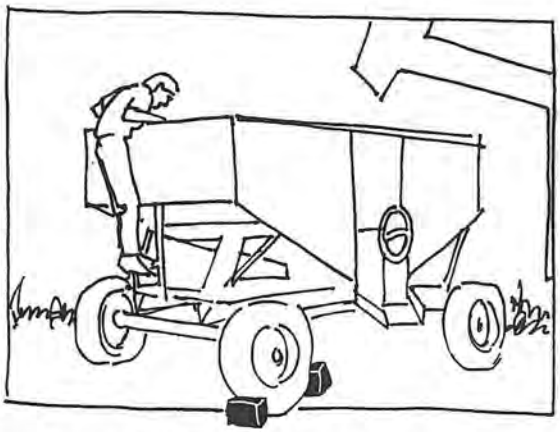


*2-5. It is a good idea to chock both sides of the wagon or implement wheels before unhitching, even if the ground appears to be level.*

If you are hitching the wagon by yourself, make sure that the parking brake is on and that the tractor is in park or in gear with the engine off before leaving the seat. Don't try to rock the tractor or the load by hand; it may move much farther than you expect.

When you unhitch a wagon, be sure that it is on level ground. Don't pull the hitch pin if there is much force on it. The wagon may crush you against the tractor. It is a good idea to chock the wagon's wheels before unhitching, even if

the ground appears to be level (Figure 2-5).

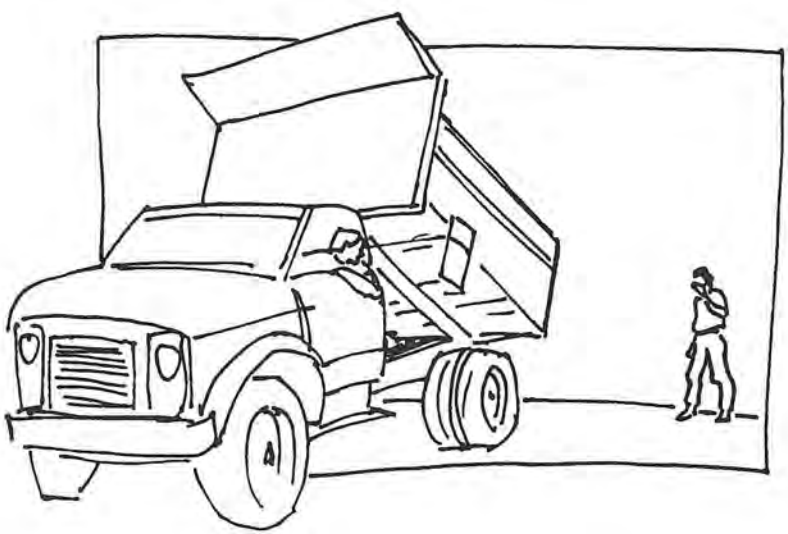


*2-6. Be sure that no one is in forage or grain wagons or trucks while they are being loaded or unloaded.*

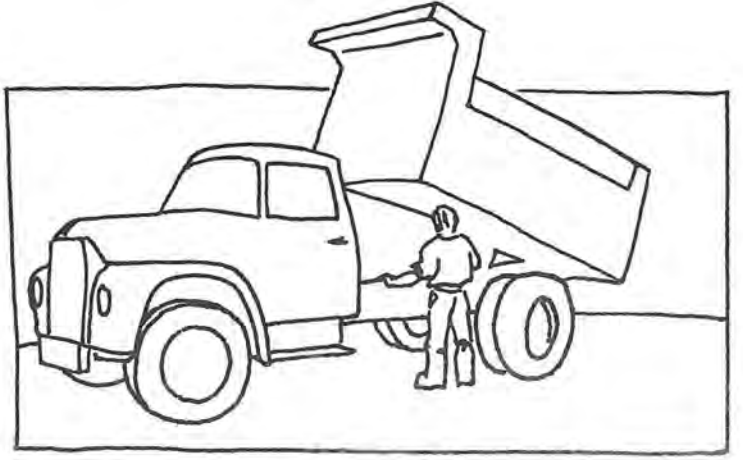
**Bulk Container Safety**

Suffocation under silage or grain was the leading cause of grain- and silage-handling fatalities for the period 1985 through 1989. These suffocations take place in gravity and auger wagons and trucks, as well as grain bins or silos.

When auger or gravity wagons empty, grain flows to a point over the outlet, then down and out of the outlet. Anyone, especially a child, can be drawn into the grain flow and be buried. The flowing grain does not offer support like still grain. A person will usually sink no deeper than several inches to a foot in still grain. Flowing grain cannot develop this support. Workers can rapidly sink thigh-deep and will then be unable to free themselves. A shorter person, such as a child, will be buried more quickly. In addition, some grains, such as flax and millet, cannot support a person, even when still.



*2-7. Trucks or dump wagons that are used to haul silage or grain should only be emptied on firm, level surfaces. Helpers should stand far enough away to avoid being crushed if the vehicle should overturn or if the load should dump all at once.*



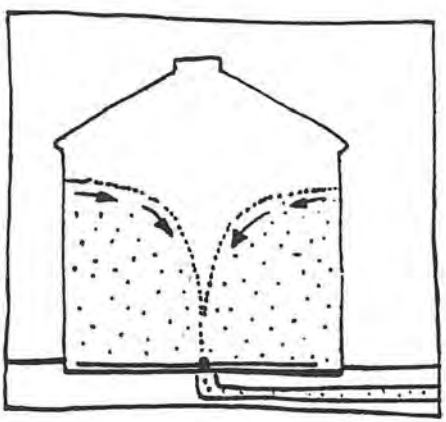
*2-8. No one should work under a raised dump box unless the box has been securely blocked.*

People can also suffocate by being buried in a wagon or truck that is being filled. The victims in these incidents are often children. Suffocations in forage and grain wagons or trucks can be prevented by keeping all people, especially children, out of these vehicles while they are being loaded or unloaded (Figure 2-6).

**Dump Trucks and Wagons**

Trucks or dump wagons that are used to haul silage or grain should only be emptied on firm, level surfaces. Helpers should stand far enough away to avoid being crushed if the vehicle should overturn or if the load should dump all at once (Figure 2-7). As with all hydraulically raised devices, no one should work under a raised dump box unless the box has been securely blocked (Figure 2-8).

# section 3
# STORAGE

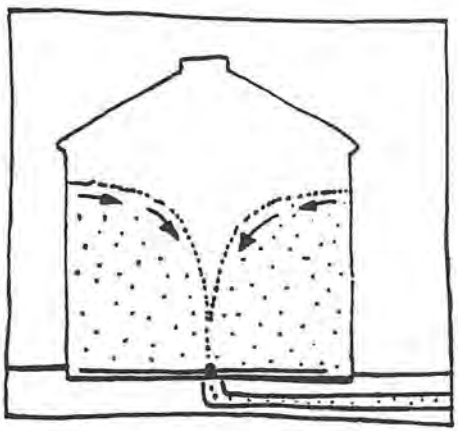


*"Habit is stronger than reason."*

*– George Santayana, 1900*
*American philosopher, writer*

Suffocation under silage or grain was the leading cause of grain-handling fatalities for the period 1985 through 1989. Many other hazards are also associated with silage and grain storage, such as being crushed by a collapse of crusted material, falling from a bin or silo, or being injured in a fire or explosion.

This section is the third part of a five-part handbook on grain- and silage-handling hazards. Each of the five sections of this handbook is meant to stand alone, so some hazards will be discussed in more than one section. If you have already read one of the other sections of this handbook, some of the material in this section may be a review for you.

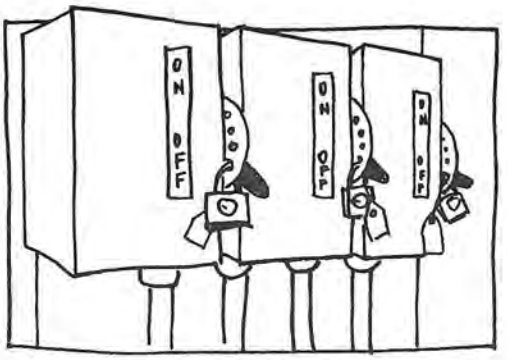


*3-1. When a flat-bottomed bin is emptied, a funnel-shaped flow pattern usually develops. Grain from the surface flows to the center, then down to the floor in a column. A worker in the bin will be carried to the center, quickly drawn under, and suffocated.*

## Suffocation

Suffocation in grain bins usually occurs when a person is buried while the bin is being emptied. Flat-bottomed grain bins are usually emptied through the center of the bin floor. Shortly after the grain starts flowing, a funnel-shaped flow pattern develops in which grain from the surface flows to the center, then down to the floor in a column (Figure 3-1). A person entering the bin will be carried to the center and quickly drawn under in this column of grain. The flowing grain behaves similarly to quicksand, making escape very difficult. While you usually only sink several inches to a foot in still grain, you can sink to your knees almost immediately in flowing grain. In 10 seconds or less, you will be thigh-deep and unable to free yourself, since the moving grain cannot develop support. Typical unloading rates will completely bury a worker in less than a minute. In addition, some grains, such as flax and millet, cannot support a person, even when still.

The suffocation hazard can be eliminated by never entering a silage- or grain-

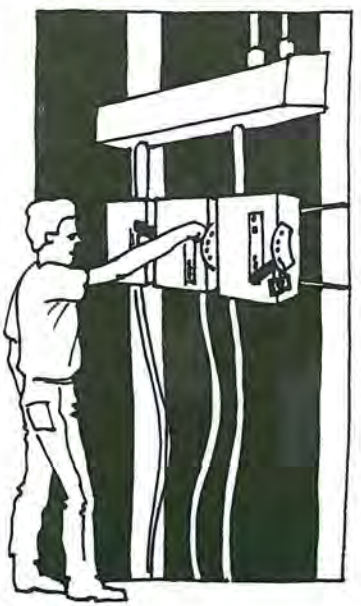



*3-2. Never enter a forage- or grain-storage structure when it is being loaded or unloaded. The power to all conveying equipment, automatic and manual, should be shut off, locked, and tagged to prevent unexpected operation.*

storage structure when it is being loaded or unloaded. The power to all conveying equipment, automatic and manual, should be shut off, locked, and tagged to prevent unexpected operation (Figure 3-2).

Consider installing a permanent ladder on the inside of all grain bins. If workers **must** enter the bin and unloading starts in spite of proper shut-off, lock-out precautions, they may be able to get to the ladder and climb to safety. Without a ladder, a victim's only hope for survival may be to keep walking around the perimeter of the bin to avoid being drawn to the center with the grain.

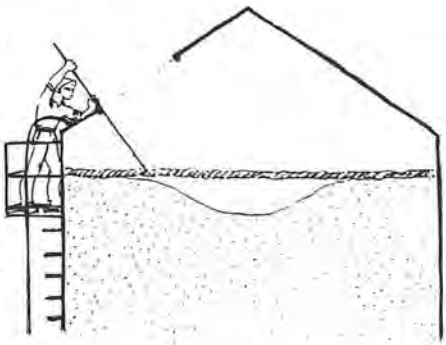
It has been suggested that permanent safety ropes be placed in grain bins, either hung from the center of the roof or stretched across the grain surface from the roof entrance. Data from human overhead pull- and grip-strength tests and friction tests in grain bins suggest that such ropes are of little value. In fact, these ropes may increase the likelihood of a suffocation by giving people a false sense of confidence that it is safe to enter a bin which is being unloaded. The data indicate that once workers become waist deep, they will not have the strength to hold onto the rope, let alone pull themselves out. The drag forces are so great that many people could not hold on once they were only thigh-deep in the flowing grain. There is also evidence that the drag force against a rope hung from the center of the bin may be able to collapse the roof. The **only** way



*3-3. To avoid burial and suffocation under flowing grain, shut off, lock, and tag the power to all loading and unloading equipment before workers enter a bin.*

to completely avoid burial and suffocation under flowing grain is to shut off and lock out the power to all loading and unloading equipment before workers enter a bin (Figure 3-3).

Caked or frozen grain or silage is also a suffocation or crushing injury threat. If a bin has been partially emptied below a crust of grain, someone who steps on the crust while attempting to break it up can fall through and become buried. Workers should always assume all surfaces are bridged. Break up surface crusts from outside the bin with a wooden pole—not a metal one—or a weighted line thrown through the bin door (Figure 3-4). Metal poles, pipes, or lines are electrocution hazards, since they may contact overhead power lines near the grain bin. You might consider mechanical agitation or vibration equipment to assist in breaking up badly crusted grain from outside the bin. Contact your Cooperative Extension Service safety specialist or local equipment dealer for more information about such equipment.

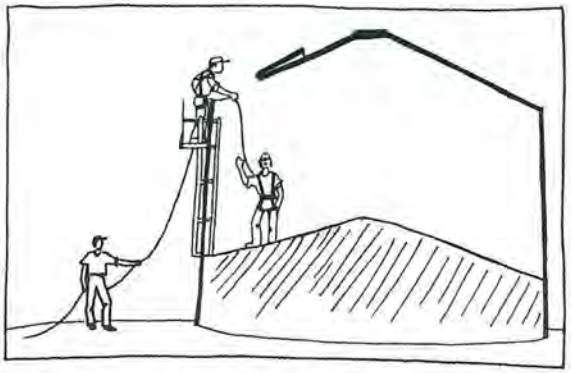


*3-4. Surface crusts or material sticking to bin walls should be broken up from outside the bin with a wooden pole or weighted line. Never walk onto a surface crust or enter a storage structure below material sticking to the walls.*

Frozen or crusted material sticking to walls can fall on someone trying to break this material loose, crushing or suffocating the worker. Workers should always remember that it takes very little grain to entrap and suffocate a person. Never enter a storage structure below material that is sticking to the sides of the structure or caked on a wall. Break up this material from above.

A suffocation hazard also exists from the gases given off from spoiling grain. For example, the carbon dioxide ($CO_2$) given off is heavier than air and will collect above the grain surface. You cannot smell, see, or taste the $CO_2$. If enough gas has collected to decrease the oxygen concentration from the normal 21 percent to less than 19.5 percent, you will think less clearly, become drowsy, lose consciousness, or even die. Workers who fall through crusted grain can be killed by $CO_2$ that has collected under the crust, even if they are not completely buried.

If a grain bin must be entered, three people should be used (Figure 3-5). The person entering the structure should wear a safety belt or harness attached to a



*3-5. If a grain bin must be entered, three people should be used. The person entering should wear a safety belt or harness and lifeline. A second person should stay at the bin entrance to watch the person inside the bin. The third person should stay on the ground to go for help or assist in freeing the person in the bin, if necessary.*

lifeline. A second person should remain at the bin entrance to watch the person inside the bin and keep tension on the lifeline at all times to prevent the worker in the bin from slipping under the grain. The third person should remain on the ground to go for help or assist in freeing the person in the bin, if necessary. All of the unloading equipment should be turned off, locked, and tagged. If the bin has a ventilating fan, it should be turned on to thoroughly ventilate the bin before entry and should be left on as long as a person is in the bin.

## Silage Structures

Fermenting silage produces nitric oxide (NO), nitrogen dioxide ($NO_2$), and nitrogen tetroxide ($N_2O_4$). $NO_2$ and $N_2O_4$ are respiratory irritants. Low concentrations of $NO_2$ can cause coughing, difficulty in breathing, or nausea. Higher concentrations may cause the lungs to fill with fluid, which can result in death. These symptoms may be immediate or may be delayed for several hours, for example, until night when the person is asleep.

The highest concentrations of these gases are produced during the first 48 hours after silage is added to the silo, but these gases may be present for the next 4 weeks. The presence of $NO_2$ is sometimes indicated by dead birds or flies under the silo chute. A buildup of gas may be reduced by keeping the silo chute doors open to the silage level, since all three gases are heavier than air. A space between the bottom of the door and the top of the silage, or low spots in the silage surface, can still collect fatal concentrations of gas. Workers could inhale fatal amounts of gas if they fall, or bend over to work or pick up a tool, or even if the gas is stirred up by a draft or the workers' activity. It is best not to enter a

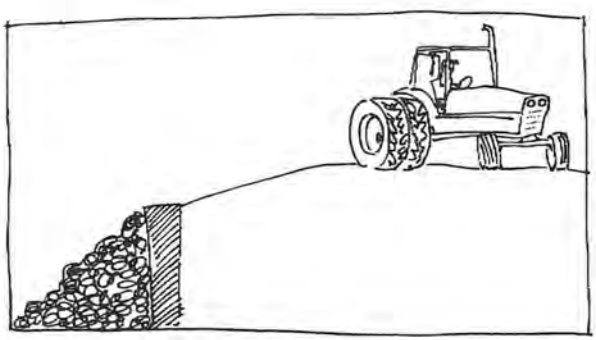
silo for 3 to 4 weeks after silage has been added. If entry must be made during this time, the silo should be ventilated with the silage blower or ventilation fans for at least 30 minutes before entry and should be left on as long as someone is inside. Longer ventilation times should be used if the silo is more than 24 feet in diameter or if the silage surface is more than 15 feet from the top of the silo. Even if 4 weeks have past since silage was added, it is a good practice to thoroughly ventilate the silo before an initial entry is made.

Agriculture Canada has studied the ventilation provided by forage blowers. They recommend attaching wire-wound, flexible, exhaust ducting to the output of the blower pipe so that the end of the ducting is 15 to 30 feet above the silage surface. The flexible ducting prevents the silage distributor from breaking up the air stream and directs the fresh air flow toward the silage surface where the hazardous gases collect. During the Agriculture Canada tests, ventilation was best when all of the chute doors were closed but the roof panel was open. Workers should not climb the chute of a newly filled silo to close the doors or attach ducting, however, since they may inhale $NO_2$ during these activities.

Since silo gases are heavier than air, they may flow down the silo chute and collect in the silo room, if there is one. To reduce the chances of developing a hazardous gas concentration, doors between the silo room and other parts of the building should be closed and the silo room's windows and doors to the outside should be opened. This safeguard should also be maintained for 4 weeks after silage has been added to the silo.

**Bunker Silos**

When tractors or other vehicles are used to pack silage into bunker silos, overturns are a definite possibility. The vehicle chosen for this task should have a rollover protective structure and a seat belt. Equipping a tractor with dual wheels may increase its lateral stability and help prevent a sideways overturn (Figure 3-6).

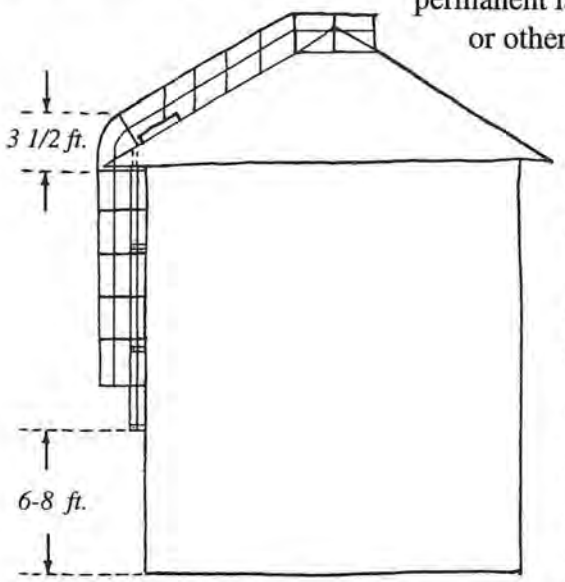


*3-6. Tractors that are used to pack bunker silos should always have ROPS and seat belts, since overturns are likely. Dual wheels will increase the tractor's lateral stability.*

Crushing hazards are also present when bunker silos are unloaded. Workers unloading a bunker silo with a front-end loader have been crushed when silage from the top of the pile fell onto their tractor. When removing silage from the pile, always start at the top of the face and work down. Never let an overhang develop. By removing silage from the top of the face first and sloping the face slightly toward the pile, the chance of being crushed is reduced.

## Falls

Falls from machinery and structures were the third largest cause of grain- and silage-handling fatalities for the period 1985 through 1989. Falls from structures accounted for about 80 percent of these fatalities. The fatality data show that even falls that seem fairly short, 12 to 20 feet for example, can kill a person. Some falls can be prevented by simple safety practices. For example, keep all ladders in good condition and avoid climbing them in wet or icy conditions. Consider using a locking cover or pull-down section for the first 6-8 feet of permanent ladders to prevent access by children or other unauthorized persons (Figure 3-7).



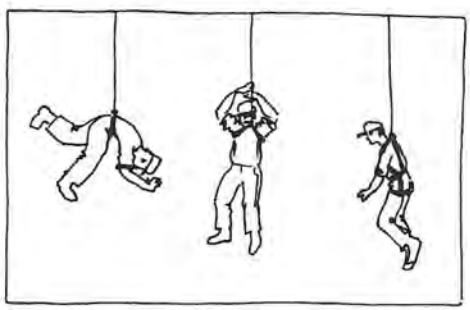

*3-7. Consider installing guardrails along the roof ladder and around the center roof cover. These guardrails should have top, middle, and toeboards, with the top board 3 1/2 feet high.*

Permanent ladders more than 20 feet long should be surrounded by a safety cage which will support the weight of two workers. The American Society of Agricultural Engineers also recommends construction of rest or work platforms at 30-foot intervals.

Falls can occur as workers move from the vertical exterior ladders on grain bins to the bin roof or through a bin entrance. Handrails extending 3 1/2 feet above the end of ladders will help workers get onto and off the ladders. Each handrail should be able to support the weight of one worker.

To prevent falls while accessing the center roof openings on grain bins, consider installing guardrails along the roof ladder and around the center roof cover. Ideally, these guardrails should have top, middle, and toeboards, with the top board 3 1/2 feet high (Figure 3-7). Also consider using stair treads instead of a roof ladder and a level work platform instead of roof cleats around the center roof cover, to provide a safer footing. These railings, stair treads, and work platforms can be installed on bins that you already have and on new bins that you may be putting up.

Equipment is also available to prevent serious injuries in case a fall does occur. Most of this equipment uses a waist belt or body harness and a lanyard, which is a short rope or strap, to limit the distance a worker can fall. A body harness is better than a waist belt or a loop of rope around the waist or under the arms, since the harness spreads the force of a fall over a larger part of the body (Figure 3-8). A waist belt or a loop of rope can inflict severe injuries if it is used to stop a fall. Think of how uncomfortable it would be to hang from your waist by a rope loop for even a short time. Falls cause **much** greater forces than just hanging. If you are selecting a harness, be sure it will fit all of the workers who will be using it. Harnesses with leg, waist, and chest straps and D-ring attachment points in the middle of the back offer the best protection.



*3-8. Safety harnesses are preferred to rope or a safety belt, since a belt or a loop of rope around the waist or under the arms can inflict severe injuries if a fall occurs.*

Several systems are available to limit the distance a worker can fall from a ladder. These systems have a fall arresting device that runs on a rail along the ladder or on a lifeline hung along the ladder. The fall arrester allows a worker to freely climb up and down the ladder but grabs the rail or life line if the worker falls, limiting the fall distance. The worker is attached to the fall arrester by a short (9-inch or less) lanyard. Longer lanyards may prevent the fall arrester from working correctly.

Limited fall protection may be provided by devices that connect the body harness or safety belt to hooks worn or carried by each of the climber's hands.

On some of these devices, the hooks will latch around the ladder rungs, rather than just hook over the rung, and are released only by the climber's grip. If the climber only moves one hand at a time, one of the two hooks will be latched to a ladder rung at all times.

When using a fall arresting device, it is important to remember that seemingly short falls can generate very large forces. Components meant to limit a free fall to a distance of 2 to 6 feet should be able to withstand a 5,000-pound load and should be selected very carefully. Fall arrest gear should not allow falls greater than 6 feet. The shorter the fall, the lower the chance of an injury.

If you are repairing or constructing a fall arrest system, try to obtain a rope with end loops woven by the manufacturer. Knots reduce the strength of ropes by about 50 percent. Woven end loops are much stronger. Passing a rope around a sharp corner will reduce the rope's strength by about 70 percent. To prevent these strength losses, snap hooks should be used to attach the safety rope to the worker and the structure. Snap hooks that are meant for animal confinement should not be used unless they have been approved for fall protection use. Also avoid snap hooks that are not self-locking, that is, where the keeper is held only by a spring. Twisting a hook that is not self-locking around a ladder rung or rope, for example, can open the keeper, allowing the hook to come free. Synthetic materials such as polypropylene, polyester, and nylon should be used for safety ropes. Synthetic materials offer some cushioning when they stop a fall, reducing the chance for an injury. Wire rope should be used if hot work, such as welding, is to be done, even though it offers reduced cushioning. Remember that wire rope should not be used near electrical wires.

Safety ropes should be stored carefully. Sunlight, moisture, and many chemicals greatly reduce the rope's strength. Safety specialists recommend that safety ropes be replaced every 7 years, even if they do not appear to be damaged. Some fall protection equipment is not compatible with equipment from other manufacturers. If two brands are mixed, a failure may occur. Consider purchasing fall prevention and protection equipment from a safety gear manufacturer or retailer who has experience with these devices.

### Fires, Explosions, and Electrocutions

Fires, explosions, and electrocutions are not as common as falls, but can have equally severe results when they do occur. Fires and explosions in grain

storage are generally due to dust or grain-drying equipment. The risk of a dust explosion or fire can be reduced by preventive maintenance. Regularly checking and servicing bearings, belts, and conveyors will help to prevent overheating from lack of lubrication, slippage, or rubbing. Thoroughly ventilating the bins with the dryer fans before igniting the dryer will reduce the risk of a fire or explosion from leaking fuel. If you use liquified petroleum (LP) gas for grain drying, be sure to use pipe, tubing, hose, fittings, and valves specified for LP gas use by the manufacturer. LP storage tanks should not be located right next to each other or right next to buildings or grain dryers, to reduce the risk of a fire or explosion. The National Fire Protection Association recommends distances between LP storage tanks and buildings or between adjacent tanks based on the tank capacity. Check with your gas supplier or county extension agent to be sure that your LP tanks are located according to these recommendations.

Regularly cleaning grain material from the inside and outside of grain dryers will decrease the chances of a fire. The risk of a fire can also be reduced by keeping the air intake screens clean and in good condition so combustible material cannot be pulled in with the air.

Grain dryers may have a variety of automatic controls, including:

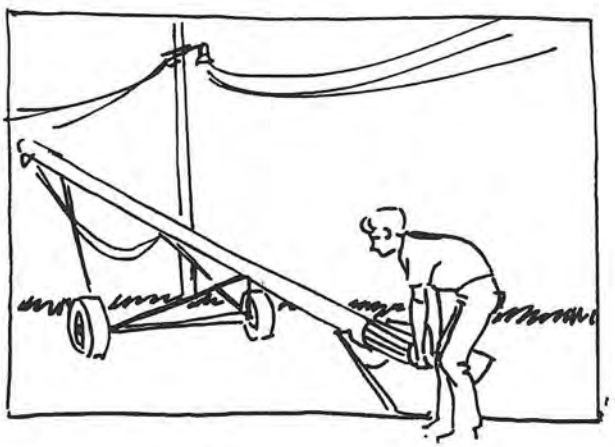
- a valve to halt the fuel flow if the ignition fails
- a valve to halt the fuel flow if the air flow fails
- air temperature limit controls
- fire prevention equipment (automatic dampers, for example)

All of these controls should be checked regularly, since their proper operation helps to reduce the chances of a fire or explosion.

Fires are also caused by electricity. Permanently connecting all fans, dryers, and unloading equipment with underground wiring will help to reduce faulty electrical connections. For 120-volt electrical outlets, consider installing ground fault circuit interrupters, commonly called GFCI's. These devices will shut off power to a faulty electrical circuit before that circuit leaks sufficient current to kill a person.

When revising or adding electrical circuits, make sure whoever does the work is familiar with the recommended practices for agricultural wiring. Agricultural wiring environments are more harsh than those in the home. You can create electrocution or fire hazards if the proper practices and equipment are not used.

# section 4
# CONVEYING



*"Care and diligence bring luck."*

*– Thomas Fuller, M.D., 1732*

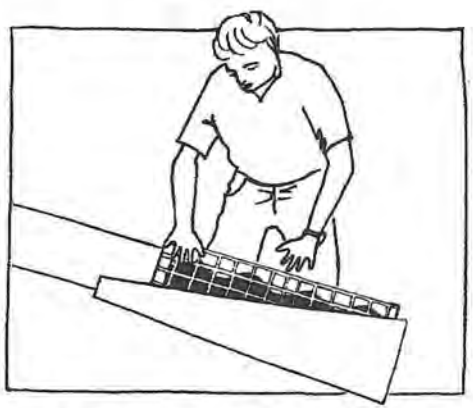
*English physician, writer*

Auger entanglements involving all types of equipment, such as portable augers, combines, and grain wagons, were the second largest single source of grain-handling fatalities for the period 1985 through 1989. This section will discuss ways to reduce the risk of losing a limb or dying from an auger entanglement by avoiding contact with grain-conveying equipment and by protecting yourself in case contact should occur.

This section is the fourth part of a five-part handbook on grain- and silage-handling hazards. Each of the five sections of this handbook is meant to stand alone, so some hazards will be discussed in more than one section. If you have already read one of the other sections of this handbook, some of the material in this section may be a review for you.

## Avoiding Machine Contact

To prevent contact with grain-conveying equipment, try to work on a stable, level surface. For example, place portable conveyors on dry, level ground. Consider placing gravel on the unloading areas to provide better footing. Grain spills should be cleaned up between each load, only after all of the equipment has been shut off and has stopped rotating, so workers are not standing on loose grain. The chances are less chance that workers will slip and become entangled if they work with a secure footing.



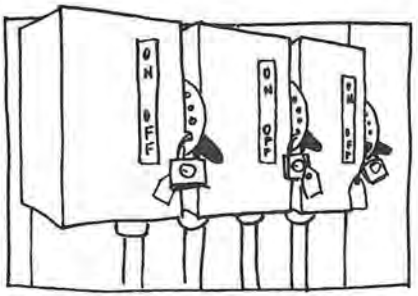
*4-1. Guard the intake areas of all augers to protect yourself from injury in case you contact the machinery.*

Keep your hands and feet from the intake areas of augers and elevators. For example, don't level or redirect the flow of grain into the auger or elevator with your hands or feet. Avoid the temptation to use a paddle elevator as a ladder. The risk of injury or death from falling, from becoming caught in the elevator, or from having the elevator collapse on you is not worth the few seconds saved.

## 4-2 Guarding

Guarding can help protect you from injury in case you do slip and contact the machinery. Belts, chains, intake areas, and drive shafts of conveying equipment should be guarded. Guards should be used on the intake areas of portable grain augers and augers that are part of other machines (Figure 4-1). Guards can be installed on older equipment. Pay special attention to children, since their hands and feet may be small enough to fit through the normal-sized openings of the intake guards. Consider installing flexible flighting on the intake portion of grain augers. Although this type of flighting may have a reduced grain-handling capacity, it may decrease the chance of injury if contact should occur.

Some areas are specifically not guarded. The intake areas of the unloading augers in grain bins are often not guarded, since attempting to clear a clogged guard inside a bin can lead to entrapment and suffocation hazards. Grain bins should never be entered when grain is being loaded or unloaded.



*4-2. Shut off, lock, and tag the power to conveying equipment before servicing or unclogging it. Don't take the chance that the equipment may start or be started while you are working on it.*

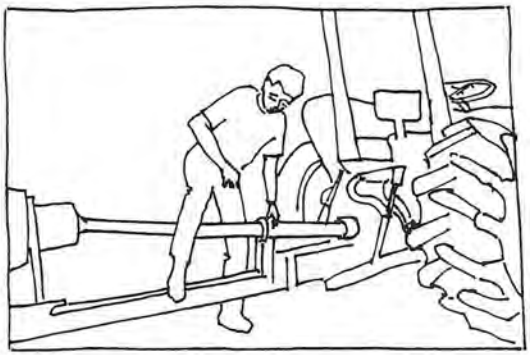
Always shut off and lock the power to conveying equipment before servicing or unclogging it (Figure 4-2). If the equipment is driven by a power take-off (PTO), shut off the tractor and take the key; if it is electrically driven, turn off and lock the power. Don't take the chance that the equipment may start or be started while you are working on it. If you are working with a blower, make sure the flywheel has stopped before performing any service.

### Power Take-Offs and Drivelines

Many conveyors are PTO-driven. Although it is common sense to avoid contact with a driveline, injuries still occur when people step across or reach over or under a PTO shaft or driveline (Figure 4-3).

Even though you may take steps to avoid PTO contact, all shafts and

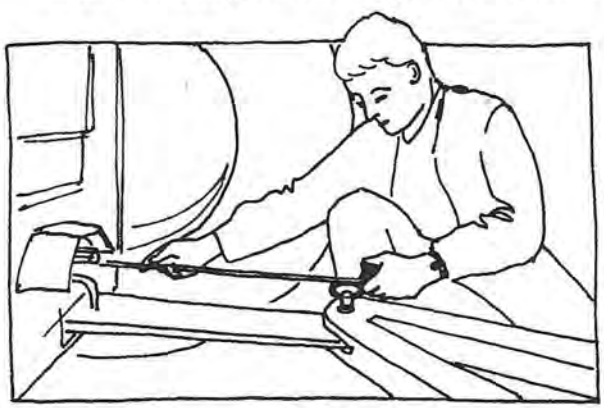
drivelines should be shielded to help prevent injury if something should go wrong. The irregular shapes of the shafts and flexible joints entangle loose clothing and hair very easily. Shields that were designed to rotate separately from the shaft inside should do so easily. This condition should only be checked, of course, with the shaft stopped. Rotating shields should be smooth and free from cracks or sharp edges that could entangle loose clothing or hair.



*4-3. Although it is common sense to avoid contact with a driveline, injuries still occur when workers step across or reach across or under a PTO shaft or driveline.*

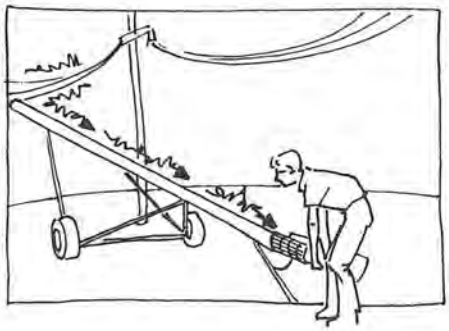
The clothing worn while working around equipment, particularly PTO shafts, can also help to prevent entanglement. Work clothing should be well-fitting and zippered or buttoned, not open. Frayed clothes, jackets and sweatshirts with drawstrings, and boots or shoes with long shoelaces should be avoided. A shoelace or loose string, thread, flap of cloth, or the corner of a jacket can become entangled very easily.

Don't be tempted to change a conveyor's capacity by using an adapter to connect it to a PTO for which it was not intended. Using an improper PTO can cause the shaft or machinery to fail from overloading or overspeeding, and may cause severe injuries.



*4-4. Check the owner's manual for the correct distance between the tractor and the equipment when using PTO-driven implements. An incorrect hitching distance can cause the drive shaft to fail or separate, causing serious injury.*

It is also important to use the correct hitching height and distance with PTO-powered implements. Check the owner's manual for the proper hitching position (Figure 4-4). Leave stationary implements hitched to the

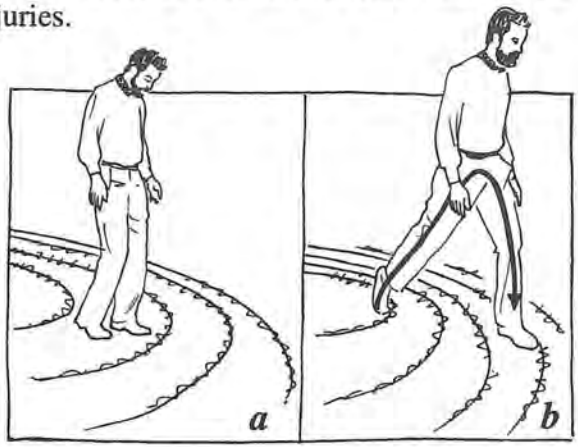


*4-5. If an auger being moved by hand contacts an overhead power line, the workers will become one of the paths the electricity takes to ground. The risk of electrocution from power line contact can be reduced by moving and positioning augers and elevators with a tractor or truck, not by hand, and by maintaining at least 10 feet of clearance around all power lines.*

tractor so the hitching position does not change. An improper hitching height or distance can cause the telescoping section of the PTO shaft to separate or fail. When a PTO shaft separates or fails, the loose or broken ends can whip around violently and may cause severe injuries.

## Moving Augers and Elevators

Portable augers, elevators, and blowers also have hazards associated with their transport and placement. Augers and elevators can contact overhead power lines or collapse if not handled properly.



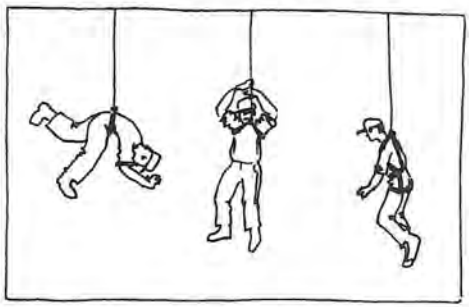

*4-6. If a tractor and auger contact a power line, the soil around the equipment will be energized. A driver who must leave the vehicle should jump clear, landing with both feet together while maintaining balance. The driver must then shuffle away using very short steps (a). Too large a step could put each foot in a different voltage zone and electrocute the driver (b).*

Before moving an auger or elevator, plan your path. Leave a minimum overhead clearance of 10 feet between a power line and the equipment. Keep the conveyor in its lowered position any time it is being moved. An auger or elevator in its lowest position has much less chance of tipping, collapsing, or contacting a power line.

If cables are used to raise and lower the auger, check them for broken strands or frayed sections. A broken cable can lead to an elevator collapse and possibly a death. Make sure that workers not absolutely necessary to raise the conveyor

are a safe distance away.

The risk of electrocution from power line contact can be reduced by moving and positioning augers and elevators with a tractor or truck, not by hand. If an auger being moved by hand contacts a power line, the workers will become one of the paths the electricity takes to ground (Figure 4-5). Helpers who are located a safe distance away (20 feet or more) can watch for power lines.



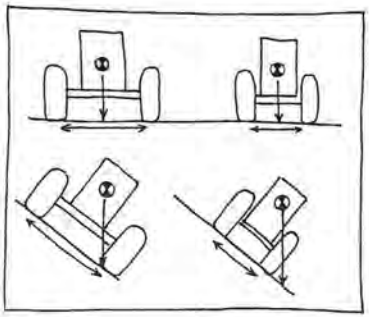
*4-7. Safety harnesses are preferred to rope or a safety belt, since a belt or a loop of rope around the waist or under the arms can inflict severe injuries if a fall occurs.*

If the conveyor should contact a wire, the driver should try to drive away to break electrical contact. Even if the vehicle cannot be moved, the driver should stay on it if at all possible. The soil immediately around equipment touching a power line will be energized. Soil near the vehicle will be at a higher voltage than soil farther away. If the driver climbs off the vehicle, he could connect two different voltage levels and become electrocuted. A driver who **must** leave the vehicle should jump away from the vehicle and wire, landing with both feet together while maintaining balance. The driver must then shuffle away from the vehicle using very short steps. Too large a step could put each foot in a different voltage zone and kill the driver (Figure 4-6).

To further reduce the chance of electrocutions from power lines, you may want to consider having the lines placed underground.

Augers and elevators should be positioned on level ground as close as possible to the storage bin or building before they are raised. While the conveyor is being raised, its wheels should be free to roll and it should be left hitched to the tractor or truck. Blocking the wheels or allowing the hitch end of the conveyor to rise can cause the conveyor to collapse. Once the auger or elevator has been raised, it can be placed in its final position with the truck or tractor.

After the auger or elevator is in position, secure the bottom or hitch end so that it can't move and block both wheels. Make sure that the conveyor tongue is placing a downward force on the tractor or truck before unhitching it. An upward force could lead to tipping and collapse of the elevator.



*4-8. If you are using a tractor and loader, space the wheels as far apart as possible. A wider tread width tends to keep the center of gravity, the average position of the weight, between the wheels, making the tractor less likely to overturn.*

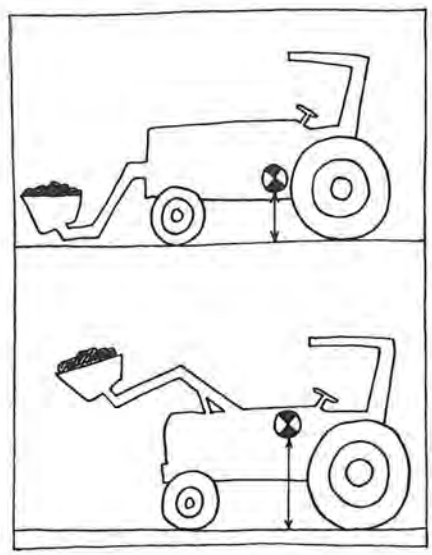
## Blower Tubes

When installing a grain or silage blower, the hazard of falling or being struck by falling objects can be reduced by assembling the blower tube on the ground, then raising the assembled pipe. While raising the pipe, make sure that the workers on ladders wear securely anchored safety harnesses. Safety harnesses are preferred to rope, since a loop of rope around the waist or under the arms can inflict severe injuries if it does stop a fall (Figure 4-7).

## Loaders

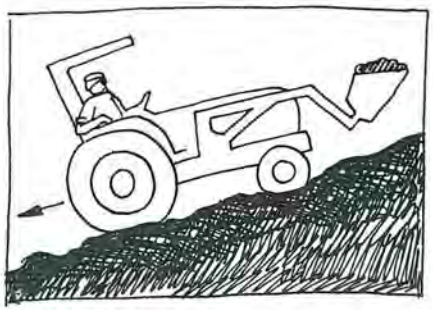
Front-end loaders and skid-steer loaders are often used to handle grain and silage. The main hazards associated with loaders are rollover injuries and crushing injuries from the bucket and bucket arms, material falling from the bucket, or material fallling from a storage pile onto the loader and operator. To increase your loader's stability and reduce the chance of a rollover, use the manufacturer's recommended weighting. If you are using a tractor-mounted loader, space the wheels as far apart as possible to increase stability (Figure 4-8).

Since raising the bucket raises the center of gravity, which makes an overturn more likely, keep the bucket height as low as possible when moving (Figure 4-9). Raise the bucket just before dumping. Use slow speeds and make slow turns or changes of direction when the bucket is loaded or raised.



*4-9. Raising a loader bucket raises the tractor's center of gravity, making the tractor top-heavy and more likely to overturn. Keep the bucket as low as possible when moving. Raise the load just before dumping it.*

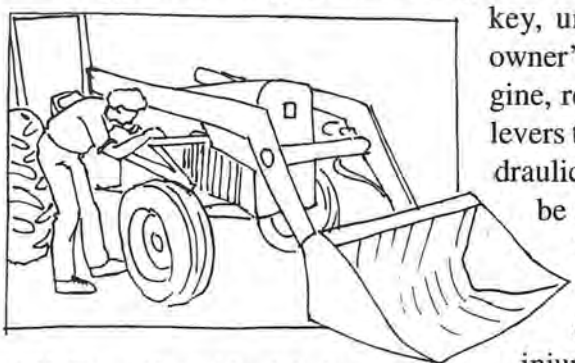
Doubling your forward speed increases the likelihood of an overturn by about four times. If you must go downhill with a loaded bucket, back down to prevent tipping to the front (Figure 4-10). To prevent side rollovers, try to load the bucket uniformly from side to side.



*4-10. Back down slopes when the loader bucket is full to avoid tipping to the front. Load the bucket uniformly side to side to prevent sideways overturns.*

Since safe practices can greatly reduce, but not eliminate, the chance of a rollover, use front-end loaders on tractors with roll-over protective structures (ROPS) and seat belts whenever possible.

Crushing injuries or deaths are also caused by getting caught under the loader bucket or between the loader and the tractor frame. To prevent a crushing injury to you or one of your helpers, make sure that the bucket is lowered to the ground, solidly blocked, or supported by the manufacturer's safety stop before servicing the tractor or loader or before attaching or removing the loader (Figure 4-11). Shut off the engine and take the key, unless otherwise specified in the owner's manual. After shutting off the engine, rock the loader's hydraulic control levers to relieve the pressure from the hydraulic cylinders. Sufficient pressure can be stored in the hydraulic system to inject fluid under the skin of a worker attempting to service the system, causing severe infection or injury.



*4-11. To avoid crushing injuries, make sure that the bucket is on the ground or solidly blocked before working on the tractor or loader. Shut off the engine and take the key, unless otherwise specified by the manufacturer. With the engine off, rock the hydraulic control levers to relieve pressure in the hydraulic system so that high-pressure fluid isn't unexpectedly released.*

It is a good practice to always lower the bucket to the ground and shut off the engine before dismounting or at the end of a work period, even if service is not planned. If the bucket is lowered and the engine is off, there is little chance of someone being crushed.

# section 5
# PROCESSING

*"Nothing's as good as holding on to safety."*

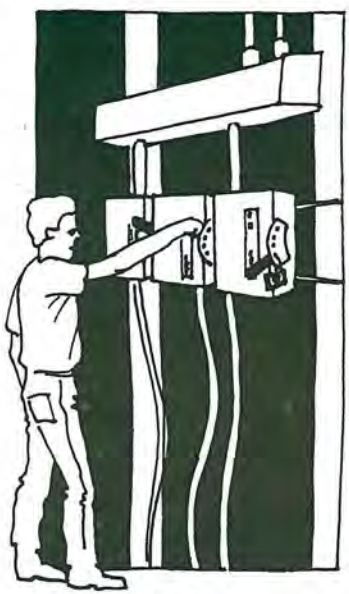
*– Euripides, c. 410 BC*
*Greek playwright*

On-farm processing activities, such as grain cleaning or grinding, are not as frequently mentioned in farm safety discussions as are other activities. Processing machines do, however, have many of the same hazards as machines that are discussed more often. Grinders and cleaners have augers and power take-offs (PTOs) that are entanglement and amputation hazards. The dust from processing machines can be a fire or even an explosion hazard. Electrically powered equipment has electrocution hazards. This section will discuss the most serious hazards associated with processing machinery and the simple things that you can do to protect yourself.

This section is the fifth part of a five-part handbook on grain- and silage-handling hazards. Each of the five sections of this handbook is meant to stand alone, so some hazards will be discussed in more than one section. If you have already read one of the other sections of this handbook, some of the material in this section may be a review for you.

## Moving Components

Make it a practice to shut off the power before attempting to unclog or service any machine. For PTO-powered equipment, shut off the tractor and take the key with you. Shut off, lock, and tag electrically powered machines (Figure 5-1). Remember that some machinery, such as grinders, will have flywheels that will continue spinning for some time after the power has been shut off. Don't attempt any service activities until you are sure that all rotating parts have stopped. Allow rotating parts to stop on their own. Attempting to slow parts quickly with a



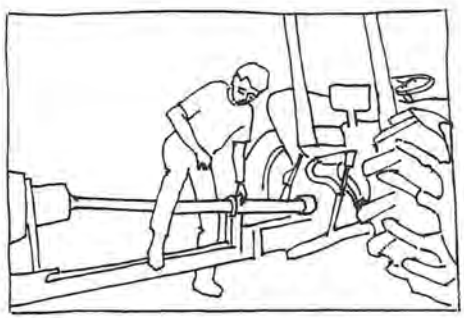
*5-1. Before servicing any electrically powered equipment, shut off, lock, and tag, the control box. Don't take the chance that the equipment could become energized while you are working on it.*

wooden stick or metal bar can cause you to be pulled into the machine or struck by flying pieces.

### Shields and Guarding

The shields and guarding on farm equipment are meant to prevent you from becoming entangled. Some of these guards may seem to get in the way when servicing or unclogging the machine. These guards cannot protect you, however, if they are not in place. You never know when you might slip or lose your balance and fall into or onto the machine, resulting in severe injuries, amputations, or death. Placing the machinery on dry, level ground and keeping your work area clean will also decrease your chance of slipping and becoming entangled. Consider placing gravel on frequently used areas to provide better footing. Clean up after the machinery has been shut off to prevent you or your tools from becoming entangled.

### PTO Safety

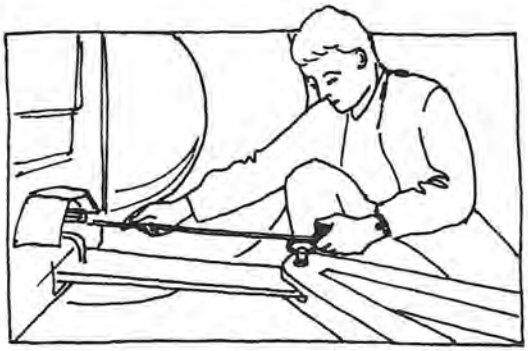


*5-2. Don't take the chance of becoming entangled in a PTO shaft or driveline. Never step across or reach across or under a rotating shaft, even if it is shielded.*

Many entanglements are caused by contact with PTO shafts. You can reduce your chances of entanglement by not stepping across, reaching across, or reaching under a rotating shaft, even if it is shielded (Figure 5-2).

Safe practices will reduce the chance of entanglement, but not completely eliminate it. Shielding is designed to prevent entanglement if contact should occur. All driveline joints, as well as the driveline shaft, should be protected by shields that are in good condition. Rotating shields should not have cracks or sharp edges, since either of these could start wrapping loose clothing or hair onto the shaft. Shields that are meant to rotate separately from the shaft inside should rotate freely. Of course, checking to see if the shield rotates freely should be done only when the shaft is stopped.

The clothing worn while working around PTO shafts, and other equipment, can also help to prevent entanglement. Work clothing should be well-fitting and zippered or buttoned, not open. Frayed clothes, jackets and sweatshirts with drawstrings, and boots or shoes with long shoelaces should be avoided. A shoelace or loose string, thread, flap of cloth, or the corner of a jacket can become entangled very easily.



*5-3. Keep PTO-powered equipment hitched to the tractor at all times. Be sure to use the hitching distance specified by the owner's manual. If the correct distance isn't used, or the equipment drifts apart, the shaft could fail or whip around and could cause severe injuries.*

It is also important to use the correct hitching height and distance with PTO-powered implements. Check the owner's manual for the proper hitching position (Figure 5-3). Leave stationary implements hitched to the tractor so the hitching position does not change. An improper hitching height or distance can cause the telescoping section of the PTO shaft to separate or fail. When a PTO shaft separates or fails, the loose or broken ends can whip around violently and may cause severe injuries.

## Grinding and Milling Hazards

Grain dust explosions are typically associated with grain elevators, but can occur wherever sufficient quantities of grain dust are mixed with air in an enclosed space. These conditions exist in some on-farm processing machinery, such as hammermills. If metal, stones, or other non-grain material enters this machinery, sparks could be created that could ignite the dust and cause an explosion. Stones or metal that enter processing machinery can also be thrown out or cause loose or broken machine pieces to be thrown out, resulting in severe injuries.

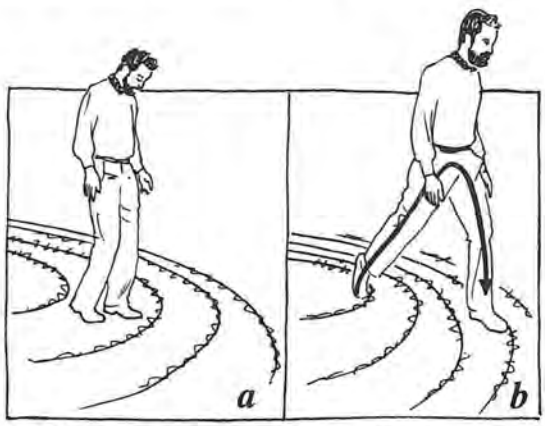
Several methods can be used to reduce the chance of non-grain material entering equipment. Screens will allow the grain to pass through, removing larger material. Magnets can be used to remove ferrous metals. Magnets are most efficient when the feed spouting is designed to slowly pass material over the mag-

nets. Material captured by screen or magnetic systems should be removed regularly to maintain performance. Pneumatic systems use air to draw grain into the grinder or mill, leaving heavier non-grain material behind. Advances in technology have resulted in durable metal detectors that can shut down equipment before any metal has a chance to enter and cause damage or injury. The combination of two or more of these separation methods will decrease the chance of non-grain material entering the mill.

## Electrical Safety

Electrocution hazards for processing machines come from two sources, mobile machines that could contact overhead power lines and electrically powered machines. When moving mobile processing machinery, plan your path in advance. Leave a minimum overhead clearance of 10 feet between a power line and the equipment.

If the equipment you are towing should contact a power line, try to drive away from the line to break electrical contact. Stay on the tractor or truck you are using, if possible. The soil immediately around equipment touching a power line will be energized. Soil near the vehicle will be at a higher voltage level than soil farther away. If you climb off the vehicle, you could connect two different voltage levels and become electrocuted. If you **must** leave the vehicle, you should jump away from the vehicle and wire, landing with both feet together while maintaining balance. After landing, shuffle away from the vehicle using very short steps. Too large a step could put each foot in a different voltage zone and could kill you (Figure 5-4).




*5-4. If equipment contacts an overhead power line, the ground around the equipment will be energized. If you must leave the equipment, jump clear and land with your feet close together while maintaining balance. Shuffle away using very short steps (a). Using too large a step could put each foot in a different voltage zone and electrocute you (b).*

To reduce your risk of an electrocution, consider permanently connecting electrical equipment with underground wiring. For 120-volt outlets, consider using ground fault circuit interrupters, commonly called GFCI's. These devices will shut off power to equipment before enough current has leaked from an electrical fault to kill you. If you are making wiring changes, make sure whoever does the wiring is familiar with correct agricultural wiring practices. The conditions in agricultural buildings are more severe than in many other locations. Improper wiring practices could increase your risk of electrocution or could cause a fire.

**Fire Prevention**

Accumulations of dust or plant residue caused by grain processing can create fire hazards. Fire hazards can be reduced by keeping drive belts tight and chains in good condition, by frequently removing dust and crop residue buildup, and by checking and lubricating bearings regularly.

# Closing Comments . . .

*"Whoever acquires knowledge and does not practice it, resembles him who plows his land and leaves it unsown."*

*– Sa'di, 1258*
*Persian poet, philosopher*

This guide has described many of the hazards associated with grain- and silage-handling activities and ways in which these dangers can be avoided. In addition to suggestions in this guide, a thorough safety program should include yearly or seasonal instruction for all people helping with these activities. By acquainting everyone with the proper operation of machinery and safety procedures, you increase the likelihood of a smooth, uneventful harvest. NIOSH recommends that warning signs and notices should be a part of an overall safety program, as constant reminders of potential hazards.

In addition to the traumatic injury hazards covered in this guide, grain-handling tasks also involve exposures which may result in health problems. These hazardous exposures come from sources such as grain dust and chemicals. Prevention of disease and illness from these and similar sources is beyond the scope of this guide. If you would like more information about protection from these or other hazards, you can contact your Cooperative Extension Service safety specialist or NIOSH at 800-356-4674.

## Authors

This document was prepared by Karl A. Snyder, Ph.D., Agricultural Engineer, and Thomas G. Bobick, P.E., Safety Engineer, of the Division of Safety Research, National Institute for Occupational Safety and Health.

## Acknowledgements

The authors would like to thank the many contributors who provided valuable assistance and suggestions during the preparation and editing of this handbook.

Ronald L. Stanevich, Acting Chief, Protective Technology Branch, Division of Safety Research, NIOSH, provided insight, long-term support and direction, and helped us to separate the grain from the chaff. Information on specific topics was provided by David L. Hard, Ph.D., Safety Specialist, Division of Safety Research, NIOSH; John A. Kramer, Extension Safety Specialist, Kansas State University; and Charles V. Schwab, Ph.D., Assistant Professor and Extension Safety Specialist, Iowa State University. Editorial, formatting, and document preparation assistance was provided by Linda L. Morton and Paul R. Keane, Writer-Editors, and Herbert I. Linn, Chief, Information Management and Dissemination Activity, Division of Safety Research, NIOSH. The artwork and document format were designed by Pavlina Vagoun-Gutierrez, Morgantown, West Virginia.

# REFERENCES

*"Knowledge is of two kinds: we know a subject ourselves, or we know where we can find information upon it."*

*– Samuel Johnson, 1775*
*English writer*

## Agricultural Injury Statistics

Etherton JR, Myers JR, Jensen RC, Russell JC, and Braddee RW [1991]. Agricultural machine-related deaths. American Journal of Public Health 81(6):766-768.

Myers JR [1989]. The national traumatic occupational fatalities: a surveillance tool for agricultural work-related deaths. National Institute for Farm Safety Paper No. 89-9.

## Auger and Elevator Safety

### *Moving and Positioning*

Aherin RA, Schultz L [1981]. Safe storage and handling of grain. University of Minnesota Agricultural Extension Service Extension Folder No. 568.

American Society of Agricultural Engineers [1992]. ASAE Standard S361.3. Safety for portable agricultural auger conveying equipment. St. Joseph, MI.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Baker DE [1987]. Hazards of grain conveying equipment. Iowa State University Cooperative Extension Service Publication Pm-1293j. Ames, IA.

Banning M [1990]. A lethal part of the landscape. Ohio Monitor 63(9):8-10.

Farm and Industrial Equipment Institute [1985]. Portable auger safety manual. Chicago, IL.

Harner JP, Kramer JA [1987]. Transport auger (screw) conveyors. Kansas State University Cooperative Extension Service Publication No. AF-164.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

NIOSH [1986]. NIOSH Alert: request for assistance in preventing grain auger electrocutions. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-119.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

### *Operating Safety*

Commonwealth Department of Primary Industry and Labour and National Service and the State Departments of Agriculture and Departments of Labour, Department of Labour and National Science [1968]. Safety in rural industry: machinery safety. Melbourne, Australia.

Farm and Industrial Equipment Institute [1985]. Portable auger safety manual. Chicago, IL.

Fletcher WJ [1969]. Avoiding elevator and auger accidents. Farm Safety Review 27(6):5-8.

Harner JP, Kramer JA [1987]. Transport auger (screw) conveyors. Kansas State University Cooperative Extension Service Publication No. AF-164.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Murphy, DJ, Williams, RC [1984]. Silo filling safety. The Pennsylvania State University Cooperative Extension Service Agricultural Engineering Fact Sheet Safety-22.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

## Bin Safety

### *Crusted or Frozen Material Hazards*

Aherin RA [1987]. Suffocation hazards associated with stored grain. Iowa State University Cooperative Extension Service Publication Pm-1293i. Ames, IA.

Aherin RA, Schultz L [1981]. Safe storage and handling of grain. University of Minnesota Agricultural Extension Service Extension Folder No. 568.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Fanning R, Hellevang K [1981]. Flowing grain entrapments. North Dakota State University Cooperative Extension Service Bulletin No. 10-SAF-4.

Farm Safety Association [1985]. Flowing grain entrapment. Fact Sheet No. F-004. Guelph, Ontario, Canada.

Field WE [1980]. Beware of flowing grain dangers. Purdue University Cooperative Extension Service Bulletin No. S-77.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere and Co. Service Training, Moline, IL.

Hood M [1972]. Don't die in the grain bin. Successful Farming 70(10):28-29.

Jepson RL [1981]. Entering grain bins safely. Kansas State University Cooperative Extension Service Bulletin No. C-624.

Kramer JA [1989]. Safety measures in handling stored grain. Kansas State University Cooperative Extension Service Bulletin No. AF-170.

Loewer OJ, Loewer DH [1975]. Suffocation hazards in grain bins. University of Kentucky Cooperative Extension Service Publication AEN-39.

NIOSH [1975]. Health and safety guide for grain mills. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No.75-144.

NIOSH [1987]. NIOSH Alert: request for assistance in preventing entrapment and suffocation caused by the unstable surfaces of stored grain and other materials. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 88-102.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

Schnieder R [1987]. Hazards of confined space. Iowa State University Cooperative Extension Service Publication Pm-1293h. Ames, IA.

### *Entry Procedures*

Aherin RA [1987]. Suffocation hazards associated with stored grain. Iowa State University Cooperative Extension Service Publication Pm-1293i. Ames, IA.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Fanning R, Hellevang K [1981]. Flowing grain entrapments. North Dakota State University Cooperative Extension Service Bulletin No. 10-SAF-4.

Farm Safety Association [1985]. Flowing grain entrapment. Fact Sheet No. F-004. Guelph, Ontario, Canada.

Field WE [1980]. Beware of flowing grain dangers. Purdue University Cooperative Extension Service Bulletin No. S-77.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere and Co. Service Training, Moline, IL.

Hood M [1972]. Don't die in the grain bin. Successful Farming 70(10):28-29.

Industrial Accident Prevention Association [1986]. Safety and health procedural manual for grain and feed dealers. Toronto, Ontario, Canada. pp. 29-30, 71-76, 83-85, 93-94.

Jepson RL [1981]. Entering grain bins safely. Kansas State University Cooperative Extension Service Bulletin No. C-624.

Kramer JA [1989]. Safety measures in handling stored grain. Kansas State University Cooperative Extension Service Bulletin No. AF-170.

Loewer OJ, Loewer DH [1975]. Suffocation hazards in grain bins. University of Kentucky Cooperative Extension Service Publication AEN-39.

NIOSH [1975]. Health and safety guide for grain mills. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No.75-144.

NIOSH [1987]. NIOSH Alert: request for assistance in preventing entrapment and suffocation caused by the unstable surfaces of stored grain and other materials. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 88-102.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

Schnieder R [1987]. Hazards of confined space. Iowa State University Cooperative Extension Service Publication Pm-1293h. Ames, IA.

### *Inside Safety Ladders*

Aherin RA, Schultz L [1981]. Safe storage and handling of grain. University of Minnesota Agricultural Extension Service Extension Folder No. 568.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Fanning R, Hellevang K [1981]. Flowing grain entrapments. North Dakota State University Cooperative Extension Service Bulletin No. 10-SAF-4.

Field WE [1980]. Beware of flowing grain dangers. Purdue University Cooperative Extension Service Bulletin No. S-77.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Hood M [1972]. Don't die in the grain bin. Successful Farming 70(10):28-29.

Loewer OJ, Loewer DH [1975]. Suffocation hazards in grain bins. University of Kentucky Cooperative Extension Service Publication AEN-39.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

### *Safety Ropes*

Aherin RA, Schultz L [1981]. Safe storage and handling of grain. University of Minnesota Agricultural Extension Service Extension Folder No. 568.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Fanning R, Hellevang K [1981]. Flowing grain entrapments. North Dakota State University Cooperative Extension Service Bulletin No. 10-SAF-4.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Hood M [1972]. Don't die in the grain bin. Successful Farming 70(10):28-29.

Loewer OJ, Loewer DH [1975]. Suffocation hazards in grain bins. University of Kentucky Cooperative Extension Service Publication AEN-39.

NIOSH [1975]. Health and safety guide for grain mills. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 75-144.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

### *Toxic Atmospheres*

Aherin RA [1987]. Suffocation hazards associated with stored grain. Iowa State University Cooperative Extension Service Publication Pm-1293i. Ames, IA.

Aherin RA, Schultz L [1981]. Safe storage and handling of grain. University of Minnesota Agricultural Extension Service Extension Folder No. 568.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Fletcher WJ [1969]. Avoiding elevator and auger accidents. Farm Safety Review 27(6):5-8.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Industrial Accident Prevention Association [1986]. Safety and health procedural manual for grain and feed dealers. Toronto, Ontario, Canada. pp. 23-28, 73-76, 83-85.

Kramer JA [1989]. Safety measures in handling stored grain. Kansas State University Cooperative Extension Service Bulletin No. AF-170.

Loewer OJ, Loewer DH [1975]. Suffocation hazards in grain bins. University of Kentucky Cooperative Extension Service Publication AEN-39.

Schnieder R [1987]. Hazards of confined space. Iowa State University Cooperative Extension Service Publication Pm-1293h. Ames, IA.

## Dump Box Safety

National Safety Council [1978]. Wagon safety. Chicago, IL.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

Schwab CV, Ross IJ, Piercy LR, McKenzie BA [1985]. Vertical pull and immersion velocity of mannequins trapped in enveloping grain flow. Transactions of the ASAE. 28(6):1997-2002. American Society of Agricultural Engineers, St. Joseph, MI.

## Fall Prevention

Aherin RA, Schultz L [1981]. Safe storage and handling of grain. University of Minnesota Agricultural Extension Service Extension Folder No. 568.

American National Standards Institute [1984]. American National Standard for ladders—fixed—safety requirements. A14.3-1984. New York, New York.

American National Standards Institute [1974]. American National Standard for ladders—fixed—safety requirements. A14.3-1974. New York, New York.

American National Standards Institute [1992]. Safety requirements for personal fall arrest systems. Standard Z359.1. New York, New York.

American Society of Agricultural Engineers [1992]. ASAE Standard S412.1. Ladders, cages, walkways, and stairs. St. Joseph, MI.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Code of Federal Regulations [1993]. 29 CFR 1910.66, Personal fall arrest systems, Appendix C. U.S. Government Printing Office, Washington, DC.

Code of Federal Regulations [1992]. 29 CFR 1926.1053, Ladders. U.S. Government Printing Office, Washington, DC.

Code of Federal Regulations [1993]. 29 CFR 1910.27. Fixed ladders. U.S. Government Printing Office, Washington, DC.

Construction Safety Association. [1984]. Fall protection for deck installation. Toronto, Ontario, Canada.

Ellis N [1988]. Suspended scaffold dangers arise from poor fall protection. Occupational Health and Safety 57(1):20-22.

Farm Safety Association [1976]. Combine safety.

Gerling JF [1976]. Safe combine operation. Oklahoma State University Cooperative Extension Service Fact Sheet No. 9417.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Marwick R [1984]. Climbing tower silos. Presentation to the International Silo Safety Conference. Farm Safety Association, Guelph, Ontario, Canada.

National Bureau of Standards [1977]. A study of personal fall-safety equipment. U.S. Department of Commerce, National Technical Information Service Publication PB-269 355.

National Safety Council [1969]. Fixed ladders and climbing devices. Data sheet 606. Itasca, IL.

National Safety Council [1978]. Farm tractor safety. Chicago, IL.

National Safety Council [1992]. Fixed ladders and climbing devices. Data sheet I-606. Itasca, IL.

Rushworth AM, Mason S [1987]. Aids to selecting fall-arrest harnesses. The Safety Practitioner 5(9):22-27.

Sulowski AC [1979]. Selecting fall arresting systems. National Safety News 120(4):55-60.

Willsey FR, Loewer DH [1976]. Using grain harvesting equipment safely. U.S. Department of Labor, Occupational Safety and Health Administration Publication No. OSHA 2287.

## Fire and Explosion Prevention

Aherin RA, Van Fossen L [1987]. Hazards of grain dryer fires. Iowa State University Cooperative Extension Service Publication Pm-1293g. Ames, IA.

American Society of Agricultural Engineers [1992]. ASAE Standard S248.3. Construction and rating of equipment for drying farm crops. St. Joseph, MI.

Balding J [1971]. Dust explosions. American Association of Feed Microscopists, Official Proceedings 19, Estes Park, CO. pp. 64A-74A.

Code of Federal Regulations [1993]. 29 CFR 1910.110. Storage and handling of liquefied petroleum gases. U.S. Government Printing Office, Washington, DC.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere and Co. Service Training, Moline, IL.

Gerling JF [1976]. Safe combine operation. Oklahoma State University Cooperative Extension Service Fact Sheet No. 9417.

Industrial Accident Prevention Association [1986]. Safety and health procedural manual for grain and feed dealers. Industrial Accident Prevention Association, Toronto, Ontario, Canada. pp. 23-28, 73-76, 83-85.

Jarrett VH [1979]. Combine harvesting safety. Utah State University Cooperative Extension Service Bulletin No. OSHMS 9-79.

Jepson RL [1981]. Entering grain bins safely. Kansas State University Cooperative Extension Service Bulletin No. C-624.

Maness JE [1980]. Explosions can be caused by faulty propane or natural gas installations. National Grain and Feed Association. Washington, DC.

Murphy DJ [1980]. Guarding against corn harvesting accidents. The Pennsylvania State University Cooperative Extension Service Agricultural Engineering Fact Sheet Safety-15.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

NFPA [1992]. Standard for the prevention of fires and explosions in grain elevators and facilities handling bulk raw agricultural commodities. In: National Fire Codes, Volume 3. National Fire Protection Association 61B.

NFPA [1992]. Standard for the storage and handling of liquified petroleum gases. In: National Fire Codes, Volume 2. National Fire Protection Association 58.

NIOSH [1983]. Occupational safety in grain elevators and feed mills. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Safety Research. DHHS (NIOSH) Publication No. 83-126.

Noyes RT, Johnson D Jr [1990]. Safety systems. Oklahoma Grain Elevator Workshop Manual—Maintenance. Oklahoma State University Cooperative Extension Service Circular E-893.

Theimer OF [1973]. Cause and prevention of dust explosions in grain elevators and flour mills. Powder Technology 8:137-147.

Welty RE [1980]. Custom combine safety. Kansas State University Cooperative Extension Service Bulletin No. AF-57.

Willsey FR, Loewer DH [1976]. Using grain harvesting equipment safely. U.S. Department of Labor, Occupational Safety and Health Administration Publication No. OSHA 2287.

## Flowing Grain Hazards

Aherin RA [1987]. Suffocation hazards associated with stored grain. Iowa State University Cooperative Extension Service Publication Pm-1293i. Ames, IA.

Aherin RA, Schultz L [1981]. Safe storage and handling of grain. University of Minnesota Agricultural Extension Service Extension Folder No. 568.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Commonwealth Department of Primary Industry and Labour and National Service and the State Departments of Agriculture and Departments of Labour, Department of Labour and National Science [1968]. Safety in rural industry: machinery safety. Melbourne, Australia.

Fanning R, Hellevang K [1981]. Flowing grain entrapments. North Dakota State University Cooperative Extension Service Bulletin No. 10-SAF-4.

Farm Safety Association, Inc. [1985]. Flowing grain entrapment. Fact Sheet No. F-004.

Field WE [1980]. Beware of flowing grain dangers. Purdue University Cooperative Extension Service Bulletin No. S-77.

Field WE, Bailey RW [1979]. Entrapments and suffocations in flowing grain. ASAE Paper No. 79-5535. American Society of Agricultural Engineers, St. Joseph, MI.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere and Co. Service Training, Moline, IL.

Hood M [1972]. Don't die in the grain bin. Successful Farming 70(10):28-29.

Jepson RL [1981]. Entering grain bins safely. Kansas State University Cooperative Extension Service Bulletin No. C-624.

Kramer JA [1989]. Safety measures in handling stored grain. Kansas State University Cooperative Extension Service Bulletin No. AF-170.

Loewer OJ, Loewer DH [1975]. Suffocation hazards in grain bins. University of Kentucky Cooperative Extension Service Publication AEN-39.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

NIOSH [1975]. Health and safety guide for grain mills. Washington, DC: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 75-144.

NIOSH [1987]. NIOSH Alert: preventing entrapment and suffocation caused by the unstable surfaces of stored grain and other materials. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 88-102.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

Schnieder R [1987]. Hazards of confined space. Iowa State University Cooperative Extension Service Publication Pm-1293h. Ames, IA.

Schwab CV, Ross IJ, Piercy LR, McKenzie BA [1985]. Vertical pull and immersion velocity of mannequins trapped in enveloping grain flow. Transactions of the ASAE. 28(6):1997-2002. American Society of Agricultural Engineers, St. Joseph, MI.

## Harvester Safety

American Society of Agricultural Engineers [1992]. ASAE Standard S318.10. Safety for agricultural equipment. St. Joseph, MI.

Commonwealth Department of Primary Industry and Labour and National Service and the State Departments of Agriculture and Departments of Labour, Department of Labour and National Science [1968]. Safety in rural industry: machinery safety. Melbourne, Australia.

Farm Safety Association [1976]. Combine safety.

Gerling JF [1976]. Safe combine operation. Oklahoma State University Cooperative Extension Service Fact Sheet No. 9417.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Jarrett VH [1979]. Combine harvesting safety. Utah State University Cooperative Extension Service Bulletin No. OSHMS 9-79.

Murphy DJ [1980]. Guarding against corn harvesting accidents. The Pennsylvania State University Cooperative Extension Service Agricultural Engineering Fact Sheet Safety-15.

Murphy DJ, Williams RC [1983]. Safe forage harvesting. The Pennsylvania State University Cooperative Extension Service Agricultural Engineering Fact Sheet Safety-21.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

Welty RE [1980]. Custom combine safety. Kansas State University Cooperative Extension Service Bulletin No. AF-57.

Willsey FR, Loewer DH [1976]. Using grain harvesting equipment safely. U.S. Department of Labor, Occupational Safety and Health Administration Publication No. OSHA 2287.

## Hitching Safety

American Society of Agricultural Engineers [1992]. ASAE Standard S318.10. Safety for agricultural equipment. St. Joseph, MI.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Kyeremanteng S, Jones ET [1987]. Safety guide for farming. Alberta Farm Safety Program, AGDEX 086-6.

National Safety Council [1978]. Wagon safety. Chicago, IL.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

Schwab CV, Ross IJ, Piercy LR, McKenzie BA [1985]. Vertical pull and immersion velocity of mannequins trapped in enveloping grain flow. Transactions of the ASAE. 28(6):1997-2002. American Society of Agricultural Engineers, St. Joseph, MI.

## Human Strength and Anthropometric Data

Eastman Kodak Company [1986]. Ergonomic design for people at work. Vol 2. New York, NY: Van Nostrand Reinhold Co., Inc.

Office of the Surgeon General-France [1981]. Manuel de Médecine du Travail et d'Ergonomie appliquées aux Armées.

Wilkinson RH [1991]. Anthropometrics and workplace design. In: Human factors: a series of quality instructional materials. American Society of Agricultural Engineers, St. Joseph, MI.

## Loader Safety

American Society of Agricultural Engineers [1992]. ASAE Standard S355.1. Safety for agricultural loaders. St. Joseph, MI.

Baker DE [1987]. Hazards of grain conveying equipment. Iowa State University Cooperative Extension Service Publication Pm-1293j. Ames, IA.

Fanning R, Hofman V [1985]. Avoid tractor overturns. North Dakota State University Cooperative Extension Service.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Kyeremanteng S, Jones ET [1987]. Safety guide for farming. Alberta Farm Safety Program, AGDEX 086-6.

National Safety Council [1978]. Farm tractor safety. Chicago, IL.

## Lock Out

Aherin RA [1987]. Suffocation hazards associated with stored grain. Iowa State University Cooperative Extension Service Publication Pm-1293i. Ames, IA.

Aherin RA, Schultz L [1981]. Safe storage and handling of grain. University of Minnesota Agricultural Extension Service Extension Folder No. 568.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Baker DE [1987]. Hazards of grain conveying equipment. Iowa State University Cooperative Extension Service Publication Pm-1293j. Ames, IA.

Benninga DA [1991]. Grain bin unloading—a review. ASAE Paper No. 91-5504. American Society of Agricultural Engineers, St. Joseph, MI.

Fanning R, Hellevang K [1981]. Flowing grain entrapments. North Dakota State University Cooperative Extension Service Bulletin No. 10-SAF-4.

Farm and Industrial Equipment Institute [1985]. Portable auger safety manual. Chicago, IL.

Field WE [1980]. Beware of flowing grain dangers. Purdue University Cooperative Extension Service Bulletin No. S-77.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere and Co. Service Training, Moline, IL.

Jepson RL [1981]. Entering grain bins safely. Kansas State University Cooperative Extension Service Bulletin No. C-624.

Kramer JA [1989]. Safety measures in handling stored grain. Kansas State University Cooperative Extension Service Bulletin No. AF-170.

Kyeremanteng S, Jones ET [1987]. Safety guide for farming. Alberta Farm Safety Program, AGDEX 086-6.

Loewer OJ, Loewer DH [1975]. Suffocation hazards in grain bins. University of Kentucky Cooperative Extension Service Publication AEN-39.

Murphy, DJ, Williams, RC [1984]. Silo filling safety. The Pennsylvania State University Cooperative Extension Service Agricultural Engineering Fact Sheet Safety-22.

NIOSH [1987]. NIOSH Alert: request for assistance in preventing entrapment and suffocation caused by the unstable surfaces of stored grain and other materials. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 88-102.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

## Machine Servicing Safety

Commonwealth Department of Primary Industry and Labour and National Service and the State Departments of Agriculture and Departments of Labour, Department of Labour and National Science [1968]. Safety in rural industry— machinery safety. Melbourne, Australia.

Farm Safety Association [1992]. Grinder-mixer guidelines. Farmsafe 17(1):6.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Industrial Accident Prevention Association [1986]. Safety and health procedural manual for grain and feed dealers. Toronto, Ontario, Canada. pp. 23-28, 73-76, 83-85.

NIOSH [1983]. Occupational safety in grain elevators and feed mills. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 83-126.

## Non-Grain Material Separation

Balding J [1971]. Dust explosions. American Association of Feed Microscopists, Official Proceedings 19, Estes Park, CO. pp. 64A-74A.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere and Co. Service Training, Moline, IL.

Radley JA [1976]. Dust explosion hazards with starch and its derivatives. Chapter 5, Starch Production Technology, Applied Science, Barking, England.

Theimer OF [1973]. Cause and prevention of dust explosions in grain elevators and flour mills. Powder Technology 8: 137-147.

## Power Line Contact

Aherin RA, Schultz L [1981]. Safe storage and handling of grain. University of Minnesota Agricultural Extension Service Extension Folder No. 568.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Banning M [1990]. A lethal part of the landscape. Ohio Monitor 63(9):8-10.

Benninga DA [1991]. Grain bin unloading— a review. ASAE paper no. 91-5504. American Society of Agricultural Engineers, St. Joseph, MI.

Dickie DE [1982]. Mobile crane manual. Construction Safety Association of Ontario. Toronto, Ontario, Canada.

Farm and Industrial Equipment Institute [1985]. Portable auger safety manual. Chicago, IL.

Harner JP, Kramer JA [1987]. Transport auger (screw) conveyors. Kansas State University Cooperative Extension Service Publication No. AF-164.

UAW-GM National Joint Committee on Health and Safety [1987]. Mobile crane safety. UAW-GM Human Resource Center, Madison Heights, MI.

## Power Unit Safety

Fanning R, Hoffman V [1985]. Avoid tractor overturns. North Dakota State University Cooperative Extension Service.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Kansas State University Cooperative Extension Service [1991]. Tractor safety presenter's guide. Publication No. GT-311.

National Safety Council [1978]. Wagon safety. Chicago, IL.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

## Reaction Times to Unexpected Events

Evans L [1991]. Traffic safety and the driver. New York, NY: Van Nostrand Reinhold, pp. 118-121.

Fletcher WJ [1969]. Avoiding elevator and auger accidents. Farm Safety Review 27(6):5-8.

Goldberg JH, Parthasarthy V [1989]. Operator limitations in farm tractor overturn recognition and response. Applied Ergonomics 20(2):89-96.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Murphy DJ [1980]. Guarding against corn harvesting accidents. The Pennsylvania State University Cooperative Extension Service Agricultural Engineering Fact Sheet Safety-15.

Olson PL, Sivak M [1986]. Perception-response time to unexpected roadway hazards. Human Factors 28(1):91-96.

Summala H [1981]. Driver/vehicle steering response latencies. Human Factors 23(6):683-692.

Wierwille WW, Casali JG, Repa BS [1983]. Driver steering reaction time to abrupt-onset crosswinds, as measured in a moving-base driving simulator. Human Factors 25(1):103-116.

## Road Safety

Code of Federal Regulations [1993]. 29 CFR 1910.145. Specifications for accident prevention signs and tags. U.S. Government Printing Office, Washington, DC.

Collmer K [1991]. Tractor safety. Kansas State Cooperative Extension Service Publication MF-984.

Fanning R, Hoffman V [1985]. Avoid tractor overturns. State University Cooperative Extension Service.

Farm Safety Association [1976]. Combine safety.

Gerling JF [1976]. Safe combine operation. Oklahoma State University Cooperative Extension Service Fact Sheet No. 9417.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Jarrett VH [1979]. Combine harvesting safety. Utah State University Cooperative Extension Service Bulletin No. OSHMS 9-79.

Kansas State University Cooperative Extension Service [1991]. Tractor safety presenter's guide. Publication No. GT-311.

National Safety Council [1978]. Farm tractor safety. Chicago, IL.

National Safety Council [1978]. Wagon safety. Chicago, IL.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

Willsey FR, Loewer DH [1976]. Using grain harvesting equipment safely. U.S. Department of Labor, Occupational Safety and Health Administration Publication No. OSHA 2287.

## Rollover Protection (ROPS)

American Society of Agricultural Engineers [1992]. ASAE Standard S383.1. Roll-over protective structures (ROPS) for wheeled agricultural tractors. St. Joseph, MI.

American Society of Agricultural Engineers [1992]. ASAE Standard S519. Roll-over protective structures (ROPS) for wheeled agricultural tractors (ISO Compatible). St. Joseph, MI.

Code of Federal Regulations [1993]. 29 CFR 1928.51, Subpart C. Roll-over protective structures for tractors used in agricultural operations. U.S. Government Printing Office, Washington, DC.

Code of Federal Regulations [1993]. 29 CFR 1928.52. Protective frames for wheel type agricultural tractors—test procedures and performance requirements. U.S. Government Printing Office, Washington, DC.

Code of Federal Regulations [1993]. 29 CFR 1928.53. Protective enclosures for wheel type agricultural tractors—test procedures and performance requirements. U.S. Government Printing Office, Washington, DC.

Fanning R, Hofman V [1985]. Avoid tractor overturns. North Dakota State University Cooperative Extension Service.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

International Organization for Standardization [1989]. ISO Standard 5700. Wheeled tractors for agriculture and forestry—Protective structures—Static test method and acceptance conditions. Geneva, Switzerland.

International Organization for Standardization [1989]. ISO Standard 3463. Wheeled tractors for agriculture and forestry—Protective structures—Dynamic test method and acceptance conditions. Geneva, Switzerland.

National Safety Council [1978]. Farm tractor safety. Chicago, IL.

Society of Automotive Engineers [1989]. ANSI/SAE Standard J1194. Rollover protective structures (ROPS) for wheeled agricultural tractors. Warrendale, PA.

Society of Automotive Engineers [1987]. ANSI/SAE Standard J2194. Rollover protective structures (ROPS) for wheeled agricultural tractors. Warrendale, PA.

## Safe Towing Weights

American Society of Agricultural Engineers [1992]. ASAE Standard S318.10. Safety for agricultural equipment. St. Joseph, MI.

Collmer K [1991]. Tractor safety. Kansas State Cooperative Extension Service Publication MF-984.

National Safety Council [1978]. Farm tractor safety. Chicago, IL.

## Shielding and Guarding

Aherin RA, Schultz L [1981]. Safe storage and handling of grain. University of Minnesota Agricultural Extension Service Extension Folder No. 568.

American Society of Agricultural Engineers [1992]. ASAE Standard S361.3. Safety for portable agricultural auger conveying equipment. St. Joseph, MI.

American Society of Agricultural Engineers [1992]. ASAE Standard S318.10. Safety for agricultural equipment. St. Joseph, MI.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Baker DE [1987]. Hazards of grain conveying equipment. Iowa State University Cooperative Extension Service Publication Pm-1293j. Ames, IA.

Benninga DA [1991]. Grain bin unloading— a review. ASAE paper no. 91-5504. American Society of Agricultural Engineers, St. Joseph, MI.

Code of Federal Regulations [1993]. 29 CFR 1928.57, Subpart D. Guarding of farm field equipment, farmstead equipment, and cotton gins. U.S. Government Printing Office, Washington, DC.

Collmer K [1991]. Tractor safety. Kansas State Cooperative Extension Service Publication MF-984.

Commonwealth Department of Primary Industry and Labour and National Service and the State Departments of Agriculture and Departments of Labour, Department of Labour and National Science [1968]. Safety in rural industry: machinery safety. Melbourne, Australia.

Farm and Industrial Equipment Institute [1985]. Portable auger safety manual. Chicago, IL.

Farm Safety Association [1992]. Grinder-mixer guidelines. Farmsafe 17(1):6.

Fletcher WJ [1969]. Avoiding elevator and auger accidents. Farm Safety Review 27(6):5-8.

Harner JP, Kramer JA [1987]. Transport auger (screw) conveyors. Kansas State University Cooperative Extension Service Publication No. AF-164.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Industrial Accident Prevention Association [1986]. Safety and health procedural manual for grain and feed dealers. Toronto, Ontario, Canada. pp. 23-28, 73-76, 83-85.

Kansas State University Cooperative Extension Service [1991]. Tractor safety presenter's guide. Publication No. GT-311.

Kramer JA [1989]. Safety measures in handling stored grain. Kansas State University Cooperative Extension Service Bulletin No. AF-170.

Kyeremanteng S, Jones ET [1987]. Safety guide for farming. Alberta Farm Safety Program, AGDEX 086-6.

Murphy, DJ, Williams, RC [1984]. Silo filling safety. The Pennsylvania State University Cooperative Extension Service Agricultural Engineering Fact Sheet Safety-22.

National Safety Council [1978]. Farm tractor safety. Chicago, IL.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

NIOSH [1983]. Occupational safety in grain elevators and feed mills. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 83-126.

NIOSH [1994]. NIOSH Alert: request for assistance in preventing scalping and other severe injuries from farm machinery. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-105.

Roome L, Brown GM [1980]. Grain center safety. Michigan State University AEIS No. 425.

Sevart JB, Berry TA [1991]. Reducing risk of grain auger systems. ASAE paper 91-5505. American Society of Agricultural Engineers, St. Joseph, MI.

Sevart JB, Thompson DA [1985]. Use of non-metallic flighting to prevent grain auger intake injuries. ASAE Paper No. MCR 85-148. American Society of Agricultural Engineers, St. Joseph, MI.

## Silo Safety

### *Blower Tubes and Blowers*

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Murphy, DJ, Williams, RC [1984]. Silo filling safety. The Pennsylvania State University Cooperative Extension Service Agricultural Engineering Fact Sheet Safety-22.

### *Gases and Ventilation*

Aherin, RA [1982]. Enclosed environments of silos and grain storage structures. Annals of the American Conference of Government Industrial Hygienists 2:129-135.

American Lung Association [1985]. Agricultural lung hazards. New York, NY.

Bilderback, B [1976]. Killer gas inside. Farm Safety Association, Ontario, Canada.

Commins, BT, Raveney, FJ, Jesson, MW [1971]. Toxic gases in tower silos. Annals of Occupational Hygiene 14(3):275-283.

Farm Safety Association [1985]. Silo gas—a swift and silent killer. Fact Sheet No. F-010, Guelph, Ontario, Canada.

Grout, AR [1974]. Silo hazards of gases and fires. The Pennsylvania State University Cooperative Extension Service Agricultural Engineering Fact Sheet Safety-4.

Groves, JA and Ellwood, PA [1989]. Gases in forage tower silos. Annals of Occupational Hygiene 33(4):519-535.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Murphy, DJ, Williams, RC [1980]. Silo gases: the hidden danger. The Pennsylvania State University Cooperative Extension Service Agricultural Engineering Fact Sheet Safety-16.

Schrottmaier, J [1982]. Protection from silo gas. Ergonomics 25(1):89-105.

## Tractor Safety

Code of Federal Regulations [1993]. 29 CFR 1910.145. Specifications for accident prevention signs and tags. U.S. Government Printing Office, Washington, DC.

Commonwealth Department of Primary Industry and Labour and National Service and the State Departments of Agriculture and Departments of Labour, Department of Labour and National Science [1968]. Safety in rural industry: machinery safety. Melbourne, Australia.

Fanning R, Hofman V [1985]. Avoid tractor overturns. North Dakota State University Cooperative Extension Service.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

Hunter AGM, Owen FM [1983]. Tractor overturning accidents on slopes. Journal of Occupational Accidents 5:195-210.

Kansas State University Cooperative Extension Service [1991]. Tractor safety presenter's guide. Publication No. GT-311.

National Safety Council [1978]. Farm tractor safety. Chicago, IL.

## Wagon Safety

### *Brakes*

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

National Safety Council [1978]. Farm tractor safety. Chicago, IL.

National Safety Council [1978]. Wagon safety. Chicago, IL.

National Safety Council [1979]. Grain harvest safety. Chicago, IL.

### *Lighting and Marking*

American Society of Agricultural Engineers [1992]. ASAE Standard S279.9. Lighting and marking of agricultural field equipment on highways. St. Joseph, MI.

Baker DE [1983]. University of Missouri-Columbia Extension Division agricultural guide: safe storage and handling of grain. Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, MO.

Code of Federal Regulations [1993]. 29 CFR 1910.145. Specifications for accident prevention signs and tags. U.S. Government Printing Office, Washington, DC.

Hathaway LR, Riney LA, eds. [1987]. Fundamentals of machine operation (FMO): agricultural safety. Deere & Company Service Training, Moline, IL.

National Safety Council [1978]. Wagon safety. Chicago, IL.


U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health