Adapted from a paper for NRAES Conference, "Silage for Dairy Farms: Growing, Harvesting, Storing and Feeding"; January 23-25, 2006; Harrisburg, PA

Natural Resource, Agriculture, and Engineering Service (NRAES)
Cooperative Extension PO Box 4557
Ithaca, NY 14852-4557 NRAES@CORNELL.EDU

Harvest and Storage Safety

Dennis J. Murphy, PhD, CSP
Professor and Extension Safety Specialist
Department of Agricultural and Biological Engineering
Penn State University

William C. Harshman
Instructor
Department of Agricultural and Biological Engineering
Penn State University

Introduction

Few farming operations invite as many different opportunities for injury or fatality as the harvesting of silage. From field harvest and transport to the farm to putting into storage and then feeding it out, workers are exposed to serious risks (Murphy 1994). Although silage harvesting and storage injury statistics are not easily collated, countless stories of PTO and harvesting machine entanglements, highway mishaps between farm equipment and automobiles, entanglement in self-unloading wagons and blowers, and encounters with silo gas exist. Increasingly, these stories include silage baggers, farm end-dump trucks, and trench and bunker silos. Noise-induced hearing loss is a constant threat with many of the machines used during harvesting and silo filling activities. Long work hours and new workers may also figure into safe silage harvest and storage considerations.

Even the feeding of silage is not without mishap. Injury reports include entanglements of workers in silage unloaders and of workers being buried by frozen chunks of silage or large volumes of collapsed silage in bunker silos. A recent fatality due to entanglement with a silage defacer used while unloading a trench silo has been reported (New York Department of Health 2005). Other possible hazards include silage dust, exposure to chemicals, silo fires and the collapse of tower silos. Silage-related injury knows no age boundary as workers and bystanders of all ages have been killed during silage harvest (Penn State Agricultural Injury Database 1980-2004).

This paper examines the hazards involved in silage making from harvest to storage and identifies the primary ways that these hazards can be eliminated, reduced or controlled. A general discussion of preparing workers and equipment is presented first, followed by a

more specific identification of hazards and safety precautions regarding the various facets of silage harvest and storage.

Harvest Preparations: Personnel

Getting people ready for the long hours of silage harvest is just as important as preparing the equipment for the task. Pre-harvest training sessions with all parties involved can help to re-focus the silage harvest team on those tasks that may have not been done since a year earlier. This training may meet OSHA regulations to train new employees and to provide update training to existing staff on an annual basis (Occupational Safety and Health Act 2005).

This pre-harvest period should also be used to prepare for the personal protective equipment (PPE) needed. Dressing for the job with sturdy, slip resistant foot-wear and close-fitting clothes is recommended. The noise levels of silage chopping equipment can exceed 85 decibels (Hass-Slavin 2005). Protection against noise-induced hearing loss for the worker can be achieved through hearing protection devices, a sound-proofed tractor cab, or by restricting the worker to a shorter time period of excessive noise. Employers are required to provide hearing protection to employees and to instruct them in the proper use (Murphy 1991).

Long harvest hours without periodic breaks and adequate nutrition can increase fatigue, drowsiness, and illness. Periodic breaks of 15-20 minutes have proven effective in keeping workers alert. A game plan for rotating work shifts to keep workers fresh and alert may be considered to decrease risk in harvesting silage. Extra persons should be kept out of the way of silage harvesting work, especially children, pets, and uninformed bystanders. Extra people standing nearby to loud, powerful equipment only add distractions to the many responsibilities of the equipment operator.

Preparing workers for harvesting should include an inspection of the fields to be harvested, the roads used to transport crops to storage, and all equipment used in the harvesting, transporting and storage processes. Newly weathered and weak ditch and stream banks, ruts, protruding rocks, fresh ground hog holes, or other obstructions to safe equipment operations may be found and fixed to the extent possible. Any changes or limitations regarding road surfaces, widths, banks, bridges or load limits can be identified (Farm Safety Association 2002).

Difficulties in entering, crossing or turning off public roads because of topography, blind corners or high traffic volume should be discussed and planned for to the extent possible. Simply telling a worker to be careful or to watch out for other traffic is not an adequate plan for these hazards. An adequate plan would entail consideration of the experience and maturity of the person operating the transport vehicle, escort vehicles, the safety condition of transport vehicles, and alternate transport routes between fields and storage locations.

Harvest Preparations: Equipment

Rollover Protection. Tractor overturns account for about 50% of the approximate 250 tractor-related fatalities annually (National Institute for Occupational Safety & Health 2004). Rollover protective structures (ROPS) are designed to create a zone of protection around the tractor operator should a rollover occur. When used with a seat belt, a ROPS will prevent the tractor operator from being thrown from the protective zone and crushed by the tractor or by farm equipment mounted or drawn by the tractor. Tractors equipped with ROPS, plus use of the seatbelt, is estimated to be 99% effective in preventing operators from being serious injured or killed from a tractor rollover. Three types of ROPS are available: a two-post frame (with solid fold down version), a four-post frame, and a ROPS with cab enclosure. ROPS also limit the damage to the tractor should a rollover occur. ROPS with enclosed cabs are the most desirable because the operator is also protected from falling off the tractor, the effects of weather that may interfere with safe operation, and more protection from crashes with motor vehicles (Murphy 2003).

Machine Guarding. Tractors, pull-type harvesters, self-propelled harvesters, unloading wagons, blowers, silo unloaders, and feeding equipment all have an assortment of rotating shafts, chain and v-belt drives, gears and pulley wheels, rotating knives, implement drawbars and jack stands. The wrap, shear, crush and pinch points created by these working parts of machines result in numerous serious injury incidents each year (National Safety Council 2004). Machinery guards and shields protect operators from injury but only if they are in place and in good condition. Hydraulic hoses should be checked for worn insulation and leaks.

Lighting and Marking. Safety-related lighting and marking of tractors, self-propelled harvesters and wagons is mostly a concern when using public roads. It is discussed here because if the issue isn't addressed prior to harvest time, it isn't likely to be addressed at all. Highway transport of farm equipment—day or night—requires safety lighting and marking. Older equipment lacking safety lighting and marking can often be retrofitted with lights and reflector kits to meet current standards. Before farm equipment is taken on the road, conduct an inspection of tractor and equipment safety lighting and marking accessories. On a daily basis make sure all lights and signals are operational, clean all the light and reflector covers, SMV emblems, and reflectors.

Table 1 shows the recommendations from the American Society of Agricultural Engineers (ASAE) for lighting and marking of farm tractors and equipment. Most manufacturers of domestic farm equipment adhere to these standards but imported tractors and equipment may not.

Table 1. ASAE Standard S279.12 *Lighting and Marking of Agricultural Equipment on Highways*

Item	**Recommendations**
Headlights	Two white lights mounted at the same level
Taillights	Two red lights mounted at the rear
Hazard Flashers	Two or more lamps with amber color to the front and red color to the rear
Turn Indicators	Two amber lamps to the front and two red-colored lights to the rear mounted with flashers
SMV Emblem	One visible at 600 ft. mounted to the rear and 2-10 ft. above the ground
Reflectors	Two red reflectors (on rear outside corners) and two yellow reflectors (on the front outside corners) of the machine
Conspicuity Material	Red retro-reflective and red-orange fluorescent color visible to mark the rear. Yellow retro-reflective material to mark the front.

Wagons. Steering components, wheel bearings, and other parts of wagon running gears must be maintained to ensure that they are kept under control during travel. See discussion below on transporting silage safely. Mounting brackets for silage boxes mounted to trucks should be inspected. These tasks should be part of pre-harvest equipment preparations. Efficient, safe harvest can proceed with minimal downtime if equipment is readied prior to the harvest.

Operator Manuals. The pre-harvest time period is also a good time to review the operator's manual for each machine involved in the silage harvest. Equipment maintenance and adjustment issues can be reviewed. Planning for daily maintenance needs such as lubrication reduces machine wear and friction. The safety recommendations for each machine can be reviewed also.

Fire Suppression Equipment. Protection of valuable tractors, harvesters, and other silage making equipment from fire loss is another pre-harvest consideration. Are fire extinguishers mounted on each piece of equipment for rapid response to a fire situation? Do you carry a fire extinguisher in trucks that visit harvesting fields? A 10 lb ABC fire extinguisher is recommended for each tractor, self-propelled machine and truck. Overheated engines, heat damaged bearings, crop debris, and dust can ignite quickly. Huge potential losses can result.

Harvest Preparations: Silos and Unloaders.

Silo storage units and silo equipment deserves attention prior to the silo filling process as well. Assuming that an upright silo is empty from the last harvest, the interior surfaces of the silo can be inspected. At least every two years this inspection is recommended. Applying an acid resistant coating to the bottom one-quarter to one-third of the inside wall surface of a new silo prior to use, and renewing that coating as required is a good practice to follow. Allowing the inner wall of the silo to dry out between fillings can increase silo life (Bellman 1996). Similar inspections may be necessary for wooden sided and concrete trenches or bunkers.

Concrete stave silos typically have the same sized staves from top to bottom, so top staves may be in original condition while bottom staves have become weakened with time and effects of silage acids. Since the staves often are fairly thin walled, the effects of silage acids may be significant.

The silo distributor/un-loading mechanisms should also receive pre-harvest inspection. Repairs and maintenance are needed at least annually. Silo unloader cables should be inspected for wear or damage before raising the unit for filling. Distribution augers should be checked for operation. Follow lock-out/tag-out procedures while these preventative maintenance checks are made. Silo inspection at this time may point out the need for silo ladder repairs, silo door and roof replacement needs, and electrical service repair.

Silage trenches/ bunkers and silage pile sites should also be inspected. Cracked side walls and corners of trenches, loosened or damaged sighting rails, and cracked, broken or rutted approaches to the trench/bunker or pile site should be repaired prior to harvest. In some instances plastic wrapped round hay bales are used for temporary trench or bunker silo side walls. If this temporary solution is used, place the round bales with their longitudinal axis perpendicular to the intended silage pack. This placement will prevent bale “kick out” as the silage is packed. Do not exceed one round bale in height for this type of temporary silage storage.

Safe Harvesting Practices

Whether a tractor-drawn harvester or a self-propelled harvester is used, silage harvesting should follow standard safety practices. Weather, field conditions, terrain, equipment readiness, and operator skill all play a crucial role in safe silage harvest. Following several well-known safety practices lowers the risk that someone will be injured during silage harvesting and storage activities. These practices relate primarily to behavioral actions that can be taken by trained workers and are largely intuitive to experienced farm workers. One reason it is important to articulate these practices is because injury-related data from silage making suggest that many workers do not consistently follow these recommended practices. The most important of these recommended safety practices are:

- Mount and dismount the tractor or harvester using a debris-free access ladder and steps and handholds. Maintain a 3-point contact as you climb. When dismounting, always face the machine.
- Use a hitch pin of sufficient grade to fasten loads securely. Secure loads to the tractor drawbar with safety pins and chains.
- Stop the machine before lubricating, adjusting, inspecting or unplugging. Wait for the cutter head to come to a complete stop before adjusting or unplugging.
- Wear safety goggles when sharpening the forage cutter knives and position yourself away from the cutter head as it is being sharpened. Sharpening stones can break and metal filings can fly away from the area toward you.
- Use reversing techniques or mechanisms to back out blockages/plugs in the machine.
- Shut down the engine and remove or pocket the keys to prevent accidental starting by another person when inspection or servicing work is needed.
- Wear snug clothing. Remove draw strings from hooded jackets and sweatshirts.
- Block wheels of all wagons not hitched to a tractor or field harvester. Consider mounting chock blocks on each forage wagon.
- Use reverse alarm devices or a remote video camera on large or oversized machines to warn others that you are backing and to increase visibility.
- Use standard agricultural hand signals to communicate with others when operating machinery or when helping with machinery movement.
- Monitor weather and field conditions as they relate to safety and adjust the harvest accordingly.
- Be sure all equipment operators are competent and trained for the jobs they are doing.

Transporting Silage Safely

Towing Units. Harvesting and transporting large quantities of silage requires tractors and self-propelled harvesters of sufficient capacity to do the job. Towed loads must be stopped safely. ASAE Standard S365.6 *Braking System Test Procedure and Braking Performance Criteria for Agricultural Field Equipment* recommends the following:

- For towed equipment WITHOUT brakes: Do not tow at speeds over 32 km/h (20 mph); or that when fully loaded has a mass (weight) over 1.5 tons (3300 lb) and more than 1.5 times the mass (weight) of the towing unit
- For towed equipment WITH brakes, do not tow at speeds over 40 km/h (25 mph); or that when fully loaded has a mass (weight) more than 4.5 times the mass (weight) of the towing unit.

Steep ends of fields require the tractor or self-propelled harvester to be able to smoothly pull the load up a hill or to be able to restrain the load while going down the hill. A heavy load can push a light weight tractor down a hill and jack knife the load against the tractor as it is pushed downhill. Even trucks hauling silage can be loaded to the point that the braking power of the unit is exceeded. Field conditions vary over time. Wet soil increases the risk of slippage. Excessively dry soil can become powdery from heavy traffic, especially on heavily traveled field access roads resulting in reduced traction, A skilled

operator may be able to quickly assess the weight of loads, soil conditions and braking capacities of powered units but a new operator may have neither the experience nor skill to make such judgments, thus exposing themselves and others to risk of serious injury.

*Wagons***.** Hauling of silage by wagons involves safety factors that have not yet been discussed. Specifically, the load and speed rating of wagon tires can be exceeded. What may be satisfactory at field speed or when pulled by a farm tractor may not be safe at posted highway speeds when pulled by a truck. For example, most wagon tires would not be rated for more than 20 mph. Farm wagons may have many years of service to their credit. Worn steering mechanisms or loose fitting hitches can result in wagons weaving back and forth behind the pulling unit. At higher road speeds this swerving can lead to an upset load or the loaded wagon drifting across the center line of the highway into oncoming traffic. Both of these issues are safety hazards to fellow motorists and are potentially citable traffic offenses.

Escort Vehicles. Use of an escort vehicle can decrease the risk associated with transporting farm commodities such as silage over public roadways, especially if the farm adjoins a busy highway. Escort vehicles should always have their hazard warning lights operating. If an older vehicle has malfunctioning hazard warning flashers, do not use it as an escort vehicle. If hauling must occur during hours of darkness, the escort vehicle greatly increases visibility. An escort vehicle can be a crucial accident prevention technique anytime a tractor and wagon has to make a left-hand turn into a field or farmstead lane, or if they need to swing into the left-hand lane to make a right turn into the field or lane.

Sharing the Road. Often times the farm vehicle operator will feel pressured to pull to the berm of the road to let trailing traffic pass. If this is necessary, signal for the turn, then pull off only where the entire tractor, implement, or truck can be removed from the roadway. Waving traffic around the farm equipment is not recommended. The farm equipment operator who motions traffic around them assumes liability for the driver who may pull out into oncoming traffic or other hazards. Use proper turning signals for each change in direction. Don’t assume the driving public will know how much space you will need for any type of turn.

*Dump Trucks***.** Trucking of silage is gaining in popularity. Harvest equipment with greater field capacity can fill wagons as fast as or even faster than a silage wagon can be unloaded. Dump trucks can keep up with the rapid harvest rate and return from the unloading site for additional loads much more quickly. An end-dump truck with a walking floor unloads quickly and is considered safer than dump bed trucks.

Dump trucks and trailers pose particular hazards in silage making. Overturns, operator crushing by an unexpected lowering of the dump bed, and contact with overhead power lines are hazards to be considered (Murphy 2005). Dump trucks should be emptied on as level a surface as possible to prevent overturns. Damp or wet silage can hang up in dump beds and create a raised center of gravity, which coupled with uneven terrain, increases the chance that the truck will overturn. Periodic inspection to determine if crop materials

are sticking to the dump bed will alert the operator to potential load hang ups that increase turnover risk. High winds can topple trucks with raised beds.

At some point in time the dump bed must be raised for inspection of parts and/or repairs and maintenance. Engage the lock mechanism that holds the dump bed in position. An unexpected lowering of the dump bed has resulted in numerous fatalities. Overhead power lines are always a hazard with dump bed trucks. Avoid contacting these power lines by using a knowledgeable assistant to watch power lines for you, and always lower the dump bed before pulling out from the dump site. Electrocutions have occurred because drivers get impatient and pull away from dump sites with beds still raised.

Heavy trucks, just like large farm tractors and combines, should not be operated too close to road banks, ditches, or streams, particularly after rains or a softening of the soil. Soils can shear away and cause a rollover. Follow the general rule of staying back from the embankment as far as the embankment is deep.

SMV emblems are not to be used on vehicles that are designed to operate in excess of 25 miles per hour. Trucks used to haul silage must use their hazard flasher lights when they are traveling under 40 mph. Do not use the SMV emblem on trucks hauling silage.

Other Safe Harvest Considerations

Custom Operators. Custom operators are often employed by silage producers to reduce machinery investment, to lower labor needs, and to ease the cash flow needs of their businesses. Custom operators will not know the farm like the owner does. They may not be familiar with terrain and field conditions or the silage storage area or equipment. They may bring extra workers to your farm. Be sure that the custom operator has inspected your fields and terrain and understands your equipment and facilities. **The farmer owner has the duty to provide a safe place of work to contractors and to warn of any hazards which cannot be eliminated.** If the custom operator has employees, ask for proof of their worker's compensation and insurance coverage. The custom operator should be providing safety training and updates to their employees as well.

Hired Youth Workers. Youth employment in agriculture is governed by US Department of Labor regulations (US Department of Labor 2005).Youth aged 14 and 15 can be employed on farms, but must have received a certificate of training under the Hazardous Occupations Training in Agriculture regulations if they are to be hired to operate tractors or powered farm equipment. Youth ages 14-15 are not allowed to be hired to work in silos within two weeks of filling under any conditions, work in horizontal silos while operating a tractor for packing purposes, nor handle anhydrous ammonia. This means there may not be any silage making tasks that they qualify to do. Youth aged 16 and above are not covered by the regulations. Children of the owners of the farm are exempt as well. Youth under age 14 are generally prohibited from employment in agriculture.

Silo Storage Methods

Silage storage structures are varied. Upright tower silos may be constructed of wooden staves, ceramic block, concrete staves, or metal. Conventional tower silos may have a roof or may be open at the top. Oxygen-limiting silos will always have a roof but in some cases they may have been modified with fill and access doors and unloading accessories such as used in conventional silos. Silo storage can also be in trenches, bunkers or piles. The trench can be an excavated hole in the ground, or could be comprised of concrete or wooden sides with concrete floor, or piled on the ground in a well drained location. Silage is also stored in large, heavy plastic bags or wrapped in plastic covered bales. Each of these methods of ensiling a crop has advantages, disadvantages and specific hazards associated with it. Table 2 outlines silage storage methods, the most serious hazards associated with the method, and safety measures that can be taken to counteract the hazards. Some hazard issues are discussed in more detail following the table.

Table 2. Silage storage methods, hazards and preventive measures

Storage Method	Major Hazards	Preventive Measures
Conventional tower	a. machinery entanglement	a. guards and shields, shut-off equip., lockout/tag-out
	b. silo gasses	b. ventilation
	c. noise	c. hearing protection
	d. fall from height	d. maintenance, 3-pt. climbing, fall protection system
	e. fire	e. proper MC and filling procedures, preservatives
	f. dust	f. respirator and eye protection
	g. frozen silage	g. proper MC, maintenance of unloader & silo
	h. collapse	h. proper filling procedures, maintenance,
Oxygen-limiting tower	a. O_2-deficient atmosphere	a. self-contained breathing apparatus (SCBA)
	b. machinery entanglement	b. guards and shields, shut-off equip., lockout/tag-out
	c. silage gasses	c. ventilation
	d. noise	d. hearing protection
	e. fall from height	e. maintenance, 3-pt. climbing, fall protection system
	f. fire/explosion	f. proper MC and filling procedures, preservatives
	g. dust	g. respirator and eye protection
	h. collapse	h. maintenance, proper filling procedures
Trench/Bunker with sides above ground level ground	a. tractor/truck rollover	a. ROPS & seatbelt, seatbelt & intact truck cab, sight rails
	b. machinery entanglement	b. guards and shields, shut-off equipment
	c. runover	c. helpers stay on sides, mirrors, border stakes
	d. fall from height	d. border guard rail/rope, hardhat
	e. fire	e. proper MC, proper packing**,** preservatives
	f. overhang, collapse	f. proper size equipment, silage face management
Trench/Bunker with sides at ground level	a. machinery entanglement	a. guards and shields, shut-off equipment
	b. runover	b. helpers stay on sides, mirrors, border stakes
	c. fire	c. proper MC, proper packing, preservatives
	d. overhang, collapse	d. proper size equipment, silage face management
Bagged	a. machinery entanglement	a. guards and shields, shut-off equipment
	b. silage gasses	b. ventilation
	c. noise	c. hearing protection
Wrapped	a. machinery entanglement	a. guards and shields
	b. runover	b. shut-off equipment
	c. noise	c. hearing protection
Piled	a. tractor/truck rollover	a. ROPS & seatbelt, seatbelt & intact truck cab
	b. fire	b. proper MC, proper packing, preservatives

Trenches/Bunkers and Piles. Silo trenches/bunkers and piles are becoming more common. These types of horizontal silos must be packed tightly to exclude oxygen from the crop. Tractor rollover may be a safety hazard as the silage is "packed". A straight drop off a concrete retaining wall is a significant risk when silage is packed above the height of the retaining wall. To achieve the required amount of silage compaction a "progressive wedge" of silage is formed during filling of the trench/bunker or pile (Tyson 1996). The wedge provides a slope for the packing operation. A progressive wedge with a maximum 3 to 1 slope minimizes the risk of roll-over. Large scale operations may involve dump truck traffic. Dump trucks can roll-over on steep silage piles as well. With packing tractors and trucks to be unloaded, communication and work coordination is a must.

To reduce trench/bunker, or silo pile incidents practice these safety points (Schoonmaker 2000):

- Use only tractors equipped with ROPS and seat belts; use the seat belt when packing silage.
- Use low-clearance, wide front end tractors.
- Add weights to the front and back of the tractor to improve stability.
- Back the tractor up sloped silage surfaces, and drive down from those areas.
- Front-wheel and front wheel-assist drive tractors provide extra traction and stability for packing and towing on silage.
- Never fill higher than the sides of the retaining wall.
- Sighting rails should be fitted to silage pit walls. The primary purpose of sighting rails is to indicate the location of the walls to the driver unloading the silage. They are not intended to hold an overturning tractor or truck.
- Mature, experienced operators only should be permitted to operate the packing tractor, unloading tractor, or forage wagon on the silage surface.

Bagged and Wrapped Silage. Silage bagging and wrapping has become an economically sound choice for ensiling corn and forage crops. Equipment needs are reduced but significant machine and equipment entanglement hazards remain. On farm operations where the transition from tower to horizontal silage storage is just taking place, unfamiliarity with new equipment and procedures may create increased risk to workers.

There may be three (3) bagging or wrapping operations involved:

- Bagging involves silage being forced by rotor blade through a horizontal bagging machine into a plastic tube. The bagger may have its own power source, or be tractor PTO driven.
- Manual bagging of wilted, round baled forage. This involves the large round bale being lifted by loader and spike pole attachment while a plastic bag is placed around the bale. This is usually a two-person task.

- Wrapping of wilted, round baled forage. This involves storing the bale in a plastic wrap applied by special equipment that rotates the heavy bale while the plastic wrap is attached.

With both bagging and wrapping procedures, turning parts (PTO shafts, rotor packing shafts of bagger units, etc.) expose workers to potential entanglement or to being run-over due to work in close quarters. Workers should avoid wearing loose or torn clothing, which easily becomes entangled in moving machine parts. Turn off the tractor to unplug plastic wrap that may have become entangled. Know where the other workers are located and how to communicate equipment movement with them. All workers should know and use agricultural hand signals to help with communications.

Other considerations when bagging or wrapping silage or wilted forage include:

- inspecting the bagger cable(s) frequently
- never leaving the bagger or bagger-tractor or bale wrapper running unattended
- providing specific instruction for helpers to understand how the equipment operates and its safety features, as well as, the hand signals used in the work area
- understanding that silo gas can accumulate nears bag openings
- keeping children and bystanders away from the work area

Silo Gas. Silage gas produced during the fermentation process from harvest through about three weeks after harvest can fill the silo and surrounding feed room and barn facility. These gases can be fatal to humans and animals alike. Nitrogen dioxide, a yellowish brown, heavier than air, bleach like odor gas predominates in a conventional silo. Carbon dioxide is an odorless, colorless, and heavier than air gas that predominates in a sealed (oxygen-limiting) silo. Both gases settle to low points in their surroundings.

Oxygen-limiting silos are not safe to enter without a self-contained breathing apparatus (SCBA) and an understanding of confined space entry procedures. Unsafe entry can result in unconsciousness within seconds and death within minutes. Few farm operations have the equipment, training and manpower to safely enter an oxygen-limited silo. If entry is unavoidable, one alternative is to contact the silo manufacturer or dealer. They may be able to assist you to find people with confined space entry training. Another source may be local or regional professional or volunteer fire and rescue services that are trained for confined space rescue. These groups are often looking for places to train and may be willing to help you if they can use your silo as a training exercise.

Entry into a conventional tower silo can be done with much less risk except for during filling and the first three weeks after filling. This period of time is the most likely time that nitrogen dioxide gas will be produced. If entry during filling or the first three weeks is necessary, ventilation with the silo blower for approximately 20 minutes and while in the silo is often recommended. Additional recommendations include lockout-tag-out the silo unloader, wear a dust mask and eye protection, and have another person standing by in case of emergency.

The effectiveness of ventilating the silo for removing or diluting silo gas to a safe level will depend primarily upon the level of silage and use of ventilation a tube. Silage gas near the top of the silo will be ventilated much more readily than silage gas located 20 or 30 feet below the top. Lower level silage may be ventilated more effectively with the use of a ventilation tube that directs fresh air down to the level of silage, but this practice is nearly unheard of in agriculture. A more sure way to safely enter the silo if silo gas is suspected is to use a SCBA, but again, these devices are very expensive and require substantial training to use properly.

Three additional safety recommendations to protect people and animals against silo gas are to: a) close the feed room door to the barn; b) post a Silo Gas warning sign at all entrances to the feed room or at the base of the silo chute; and c) lock the entrance to the feed room. These actions may save your livestock, children or others that may not recognize the dangers of silo gas. (Cromwell 2003).

Anhydrous Ammonia. Anhydrous ammonia is well known as a soil injected source of nitrogen. Also used as a silage additive, anhydrous ammonia forms a nitrogenous compound when injected into corn silage and increases its protein level. The term anhydrous means “without water” and is rapidly attracted to any form of moisture. Anhydrous ammonia is a very strong alkali and can cause severe chemical burns when it comes into contact with the skin. A freeze burn can also result due to the extremely low temperatures (-28 F) of anhydrous ammonia. Even more serious, moisture in the eyes can quickly attract ammonia, resulting in injuries ranging from mild irritation to complete and irreversible blindness. Moist tissue of the mouth, nose, throat and lungs are similarly attacked and damage. Hired workers younger than age 16 are not permitted to handle anhydrous ammonia according to the USDOL Hazardous Occupations Order in Agriculture.

Reducing Anhydrous Ammonia Risks. Working with anhydrous ammonia requires careful attention to detail. Follow these safety practices: (Baker 1993).

- Use the correct personal protective equipment (a face shield or splash-proof goggles, rubber gloves and heavy-duty, long-sleeved shirts and pants).
- Operators who are working directly with the anhydrous ammonia should carry a squeeze bottle of water in their immediate possession to treat exposure.
- Immediately remove contaminated clothing which can become frozen to the skin.
- All equipment, connectors, valves, etc., should be inspected daily.
- All labels, markings, and safety signs must be in place and clean for visibility.
- Keep untrained persons away from the anhydrous ammonia tanks and equipment.

Silage Additives. Silage additives encourage desirable fermentation, limit undesirable fermentation or improve the nutritional quality of the silage (Jones 2004). To encourage desirable fermentation, microbial inoculants, enzymes, water, or even molasses may be added. These additives are benign and pose no hazard to workers. To inhibit undesirable fermentation, acidic materials such as formic acid and proprionic acid may be added at the silage chopper or at the silage blower and incorporated into the silage mass. These acids may cause eye and respiratory tract irritation. Before using any silage additive, read and follow label directions. Specifically consider these points when using silage additive acids:

- A mechanical handling system, such as a pump transfer system, should be used to place acid additives onto the crop to be ensiled.
- When working with silage additive acids, use the following protective equipment: a face shield, long neoprene or nitrile gloves, coveralls, and rubber boots.
- A supply of water should always be kept close to silage additive acids in case of a spill or splash. If the acid gets into the eye, flood the eye with tepid (lukewarm) water for at least 15 minutes immediately after the incident. Seek medical attention.

Silo Fires

Silo fires occur for several reasons including: a) low crop moisture; b) poor distribution and packing when filing the silo; c) poor maintenance of the silo; d) secondary fermentation of aged silage; and e) in the case of oxygen-limiting silos, not closing the top hatch door or the unloading door after running the unloading. In conventional silos, fires most often surface in the top 10 feet of silage, while in oxygen-limiting silos the fire most often surfaces near the bottom unloader. A fire in either type of silo may surface within days of being placed in the silo, or not surface for several months or a few years. Over-heated silage may smolder for months, or proceed into a raging fire within several days.

Silo fires can be extremely difficult and dangerous to extinguish. Oxygen-limiting silo fires have resulted in massive explosions, killing volunteer fire fighters from their use of improper methods to extinguish them. Conventional silo fires do not normally result in explosion, but steam explosions inside conventional silos have been reported. Even with the extensive variations regarding the conditions surrounding silo fires, and the dangers involved, most can be safely extinguished if proper procedures are used. It is best if only fire fighters trained in the methods of silo fire extinguishing attempt to extinguish any type of silo fire. If a trained silo fire fighting group is not available in your area, local fire fighters may still be successful if they closely follow the procedures explained in the publication, *Extinguishing Fires in Silos and Hay Mows*, NRAES-18, 2002 Revision. Ordering information is available at www.nraes.org. It is highly recommended that all rural fire companies have this publication on hand.

Tower Silo Collapse

Two factors are generally involved in a tower silo collapse. One factor deals with the rate of silo filling and potential silage distributor equipment maintenance issues. The second factor relates to the age of the silo and the maintenance of the structure.

Silo filling must proceed at an efficient pace to assure that the crop will be ensiled at its highest quality. Tower silo distribution equipment must be in peak condition for this rapid process. Occasionally the distribution equipment malfunctions and silo filling may proceed with the operator unaware that the silage is piling up on one side of the silo. An uneven force is placed on one side of the silo: this force (pressure) translates to the opposite side of the silo as a reduced force or pressure. The result is that the lightly loaded side of the silo begins to lift, eventually causing the silo to collapse (Blanchard 2003).

Concrete stave and pre-cast silos are subject to prolonged chemical exposure to silage acids. Crops should be harvested at a moisture level that will produce high quality feed but that prevents excessive seepage. Both acetic acid and lactic acid found in silage can react with the cement in the staves and over time reduces the strength of the bond between the coarse aggregates of the staves. In effect this chemical reaction reduces the silo wall thickness. Larger silos have greater horizontal pressure on the silo walls which can force silage acids deeper into the silo walls. The lower section of the silo wall, which carries the greatest portion of vertical load, is the most affected. Higher moisture content silage also produces more acid concentration, which further deteriorates the concrete. Silo hoops, reinforcing rods, and silo hardware can also be affected (Bellman 1996).

Silo collapse is preventable with proper use and maintenance. If silo deterioration is suspected take immediate action to resolve the problem. Consider dismantling and removing deteriorating silos before they collapse and cause property damage or loss of livestock or human life.

Summary

Consistently protecting workers, livestock, equipment and property during silage harvest and filling does not occur without thought, preparation and training. Even the safest of workers can become frustrated with malfunctioning equipment and poor weather conditions and take a hazardous shortcut, or misjudge a situation and take a risky action. This is why it is always best to take steps to eliminate or control hazards ahead of time rather than to rely upon yourself or others to make the correct decision or execute the perfect action each time a hazard is encountered. You have nothing to lose by practicing safety: you have everything to lose by not practicing it.

References

ASAE Standards, 52nd Edition. 2005. S279.12. Lighting and marking of agricultural equipment on highways. St. Joseph, MI: American Society of Agricultural Engineers.

ASAE Standards, 52nd Edition. 2005. S365.6. Braking system test procedures and braking performance criteria for agricultural field equipment. St. Joseph, MI: American Society of Agricultural Engineers.

Baker DE. 1993. Using agricultural anhydrous ammonia safely. Fact Sheet GO1920. Department of Agricultural Engineering. The University of Missouri-Columbia, Columbia, MO.

Bellman HE. 1996. Deterioration of concrete tower silos. Fact Sheet 732. Ontario Ministry of Agriculture, Food and Rural Affairs. Available at: www.omafra.gov.on.ca/english/engineer/facts/90-235.htm.

Blanchard EM, C Newman. 2003. Grain storage: design and installation.

Farmnote No.64. Department of Agriculture. Government of Western Australia. Available at: www.agric.wa.gov.au/publications/farmnotes/2003.

Cromwell RP, JW Prevalt, WJ Becker. R2003. Harvesting silage safely. Fact Sheet DS 55. Animal Science Department, Florida Cooperative Extension, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL.

Farm Safety Association. 2003. Harvesting safety. Fact Sheet. Available at: www.fsai.on.ca/factsheets/Harvesting_Safety-en.pdf .

Hass-Slavin L, MA McColl, W Pickett. 2005. Challenges and strategies related to hearing loss among dairy farmers. *The Journal of Rural Health*. 21(4):329-336.

Jones CM, AJ Heinrichs, GW Roth, V. Ishler. 2004. From harvest to feed: understanding silage management. UD016. College of Agricultural Sciences, The Pennsylvania State University, University Park, PA.

Murphy DJ. 1991. Farm respiratory hazards. E-26. Agricultural and Biological Engineering Department, The Pennsylvania State University, University Park, PA.

Murphy DJ. 2003. Rollover protection for farm tractor operators. Fact Sheet E-42. Agricultural and Biological Engineering Department, The Pennsylvania State University, University Park, PA.

Murphy DJ. 1994. Silo filling safety. Fact Sheet E-22. Agricultural and Biological Engineering Department, The Pennsylvania State University, University Park, PA.

Murphy DJ, WC Arble. 2000. Extinguishing Fires in Silos and Hay Mows. NRAES-18 (2000R). National Resources, Agriculture, and Engineering Service, Cornell University, Ithaca, NY. 34 pp.

Murphy DJ, WC Harshman. 2005. Farm dump truck and trailer safety. E-44. Agricultural and Biological Engineering Department, The Pennsylvania State University, University Park, PA.

National Institute for Occupational Safety and Health. 2004. Swenson (Ed.) National Agricultural Tractor Safety Initiative. NIOSH Agricultural Safety and Health Centers, Pacific Northwest Agricultural Safety and Health Center, University of Washington, Seattle, WA.

New York Department of Health. 2005. Teenage farm worker dies during silage defacer entanglement – case report: 05ny001. Available at: www.health.state.ny.us/nysdoh/face/05ny001.html.

Occupational Safety and Health Administration. Safety and health topics: agricultural operations. Available at: www.osha.dol.gov/SLTC/agriculturaloperations/index.html.

Penn State Agricultural Injury Database, 1980-2004. Department of Agricultural and Biological Engineering, Penn State University. Unpublished data.

Schoonmaker K. 2000. Four ways to be safe around silage. *DAIRY HERD Management.* October: pp 58, 60, 62.

Tyson JT, RE Graves, DR Buckmaster. 1996. Horizontal silos. H-76. Agricultural and Biological Engineering Department, The Pennsylvania State University, University Park, PA.

US Department of Labor. Hazardous Occupations Order in Agriculture. Available at: http://www.dol.gov/dol/topic/youthlabor/agriculturalemployment.htm.