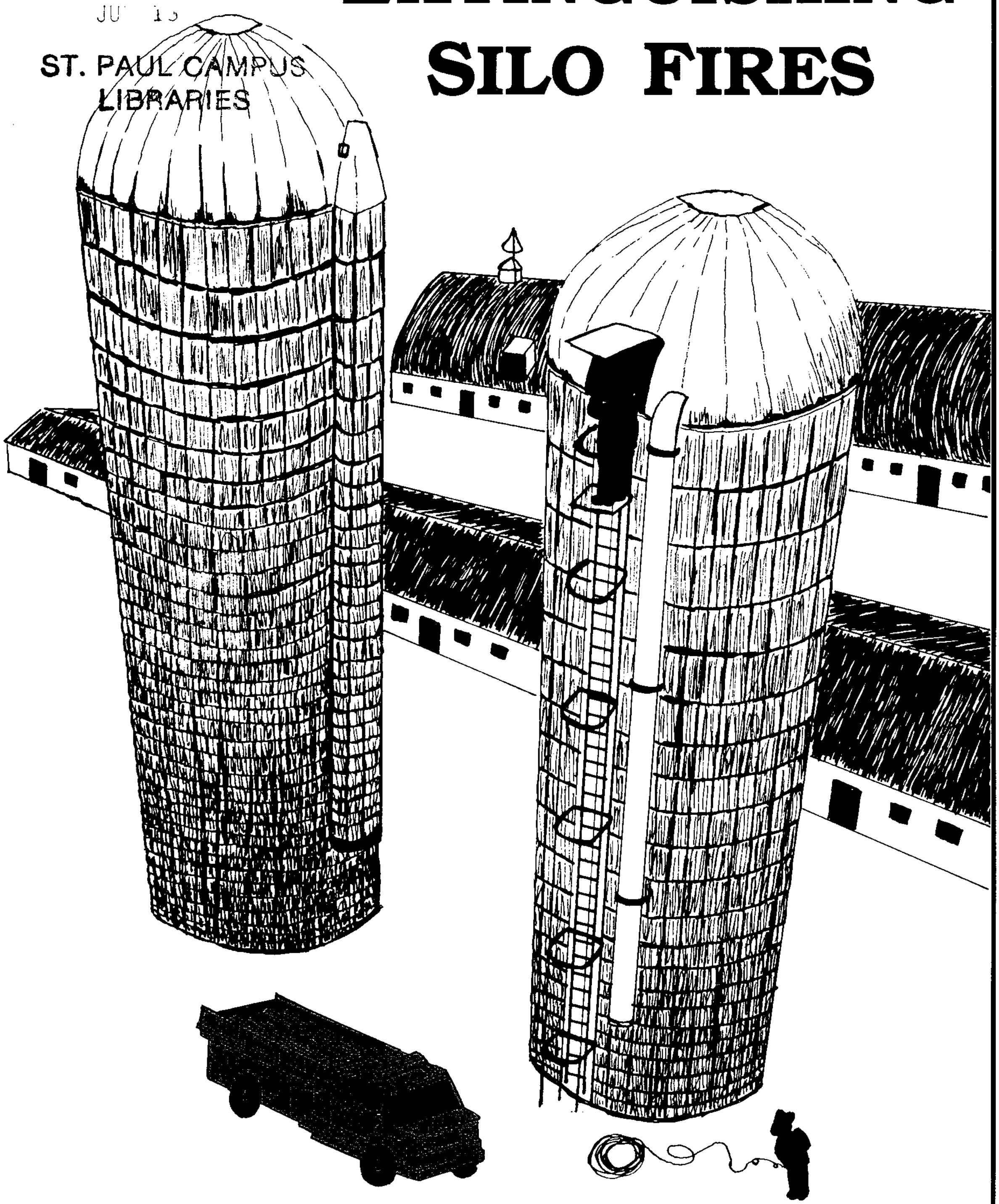
NRAES-18

EXTINGUISHING SILO FIRES



FARM SAFETY SERIES

Northeast Regional Agricultural Engineering Service

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EXTINGUISHING SILO FIRES

This manual informs the firefighter about techniques used to control and extinguish silo fires in conventional or oxygen-limiting vertical silos. It also outlines silage management and fire prevention practices on the farm. Any fire should be quickly controlled and extinguished before a disastrous loss occurs. Page 12 of this handbook is presented in fact sheet form for easy reproduction and distribution to silo owners in a fire company's district.

SILO TYPES

Two types of vertical or upright silos are common on today's farms—conventional silos (with or without roofs) and oxygen-limiting silos. Oxygen-limiting or "sealed" silos do not have outside chutes but often have bottom unloaders like the blue-enameled steel "Harvestores."

Fires occur less frequently in oxygen-limiting silos than in conventional silos, but they can be more hazardous. The approach in fighting silo fires varies with the type of silo, or its degree of oxygen deficiency. **An oxygen-limiting silo that has been converted to a conventional silo should be treated as an oxygen-limiting silo by firefighters.**

More fires occur in conventional silos because more oxygen is available to support combustion. "Chutes" developed inside the silo by fire or by certain loading mechanisms may serve as chimneys which increase the draft on adjacent burning material.

As silage gets drier, the potential for fire increases. During a dry season, fire companies may expect one fire per every 500 silos within an area. In dense farming regions, firefighters may be called to several silo fires each year. Losses of $36 million annually are estimated by the National Fire Protection Association.

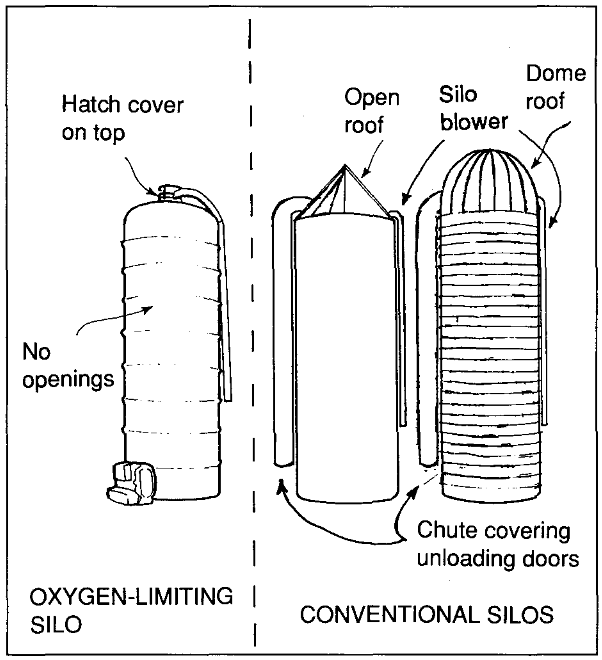


Figure 1. Types of Silos

CONVENTIONAL SILOS

Although typically constructed of concrete staves held together with pretensioned steel rods, silos are also built with reinforced concrete, steel, wood, glazed tile, or brick. Some silos are open at the top, while others have a prefabricated metal hemisphere or domed roof for weather protection, with openings for filling and inspection. Silage is removed with an electrically powered silo unloader that rests on top of the silage and conveys or blows the silage into the vertical silo chute. Small unloading doors, stacked in the silo wall, progressively open inward as the silage level lowers. These wooden unloading doors have a steel hinge and lock mechanism that serves as a ladder for climbing up the silo chute. Metal or concrete silo chutes are only 30"-36" deep, so movement with air packs, breathing apparatus, or with more than one person is difficult. The outside vertical silo chute identifies most conventional silos.

Some conventional silos have inside chutes, usually formed in the center of 24'-30' diameter silos. During filling, the silo unloader distributes silage, and it and the chute former are raised by cable and winch. During unloading, the chute former is removed, and the top silo unloader brings silage to the central shaft. There, silage drops to the bottom conveyor for delivery outside the silo.

OXYGEN-LIMITING SILOS

A typical oxygen-limiting silo has gasket-and-clamp hatches at the bottom unloader and on the roof to limit air intake. The silos are usually constructed of dark blue or green vitreous enamel-coated steel or reinforced concrete. With no feed chute or stack of wooden unloading doors, these sealed silos limit the air and oxygen reaching the silage. When fires do occur in oxygen-limiting silos, carbon monoxide may explode, especially when air is introduced in the form of spray from a fire hose. **Do not use water for cooling the "sealed" silo or for extinguishing its fire.**

FIRES IN CONVENTIONAL SILOS

Most fires in conventional silos can be extinguished by a few firefighters with little risk and a minimum of properly applied water. Injecting water into hot spots is more effective than the traditional method of pumping water on top of the silage.

Seldom are two silo fires identical, and decisions on exact procedures can be made only at the fire scene. However, certain characteristics can be expected in the majority of conventional silo fires when the following factors are considered.

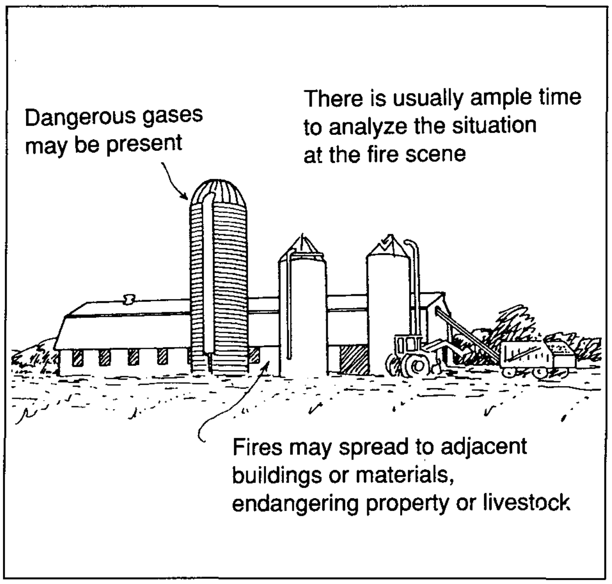


Figure 2. Factors to Consider at the Scene of Conventional Silo Fires

Safety

Always remember the prime importance of safety for firefighters and others at the scene of the fire by strictly adhering to standard safety procedures. Use full turnout gear, self-contained breathing apparatus (SCBA), and lifelines. Firefighters should maintain a "buddy" system and enter the confined space of the silo only in pairs.

Time

Unlike other fires in dry materials and flammable structures, silo fires burn slowly, so there is usually ample time at the scene to analyze the fire. Rarely will there be large flames or immediate threat to other buildings. Usually, the silage will be glowing red, with an occasional flame, like a charcoal fire. In some silos, there will be no visible flame or glowing embers, only smoke rising from beneath the top silage layer. The outside of the silo may be cool or warm and will have hot spots close to any combustion. Under these conditions, there is time to carefully examine relevant factors and plan step-by-step procedures for extinguishing the fire.

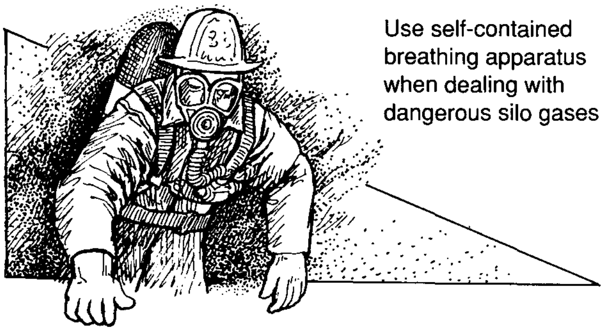
Hazards

The degree and nature of silo fire hazards vary. For instance, an exposure hazard may exist if a $300,000 barn is adjacent to the burning silo. Considerable amounts of dangerous gases may or may not be present. In some fires, flames may be seen through burned-out unloading doors, while other fires slowly smolder.

Firefighters must approach and treat each hazard appropriately.

Firespread

Fire may spread to other structures, equipment, or livestock when an unloading door burns through. Burning pieces or hot silage may break into flames as they fall down the chute and may ignite surrounding materials. In some cases, burning silage has been augered or conveyed to adjoining buildings where it ignited faster-burning materials, resulting in losses of trapped livestock.



Use self-contained breathing apparatus when dealing with dangerous silo gases

Gases

Several potentially hazardous gases are formed during fermentation of silage or as a result of a fire (see Table 1).

Carbon Monoxide is formed in small quantities during fermentation. Once a fire starts, however, incomplete combustion of cellulosic materials (such as silage) forms larger quantities of carbon monoxide that mix with air. When the amount of carbon monoxide in the air is between 12.5% and 74% by volume, the mixture becomes highly flammable.

Carbon Dioxide is present in small quantities in a flaming fire or after complete combustion. Carbon dioxide is non-flammable and heavier than air. At low concentrations, it is non-toxic, but at higher concentrations, it displaces oxygen and acts as an asphyxiant.

Nitric Oxide, Nitrogen Dioxide, and Nitrogen Tetroxide are poisonous gases which form when nitrogenous organic compounds (such as silage) burn. These gases also occur as by-products of silage fermentation. The highest levels are present during the first 48 hours after the silage is put into the silo, but dangerous levels may exist for up to three weeks. Nitrogen dioxide and nitrogen tetroxide are the most dangerous and are most likely to be present in the silo.

Chemical Additives

Occasionally, chemicals are added to corn silage to increase its nutritional value or protein content. The most commonly used chemicals are urea (which breaks down into ammonia and carbon dioxide) and anhydrous ammonia. Organic acid preservatives, such as

Table 1. Characteristics of Dangerous Gases That may be Present in Silos

GAS	HEALTH EFFECTS		EXPOSURE LEVEL MAXIMUMS [1]			PHYSICAL PROPERTIES			FLAMMABLE PROPERTIES
	Acute	Long Term	Immediate Threat to Life & Health	Short-term Exposure [2]	8-hour Workday	Density (Air=1)	Color	Odor	
Carbon Monoxide (CO)	Asphyxiant		1,500	400	50	0.97	none	none	Explosive between 12.5% and 74% by volume of air mixture. Auto ignites at 1128°F (609°C)
Carbon Dioxide (CO_2)	Asphyxiant		50,000	15,000	5,000	1.52	none	none	Nonflammable
Nitrogen Dioxide (NO_2)	Respiratory Irritant	Permanent Lung Damage	50	No standard presently in effect	5	1.16	reddish brown	strong pungent	Nonflammable, but will support combustion
Nitric Oxide (NO)	Asphyxiant		100	35	25	1.53	none	strong pungent	Nonflammable, but will support combustion
Nitrogen Tetroxide (N_2O_4)	Respiratory Irritant	Permanent Lung Damage	50	No standard presently in effect	5	1.58	yellow	strong pungent	Nonflammable, but will support combustion

1 Numbers represent parts of gas permissible per million parts of air.

2 Fifteen minute exposure, maximum of four exposures per eight-hour day with sixty-minute intervals between exposures.

propionic and acetic acids, are seldom used in silage and are easily volatilized. These chemical additives pose no additional fire hazard.

CONTROL OF FIRES IN CONVENTIONAL SILOS

The procedures for extinguishing fires vary with each situation. Consider the following steps, even though the sequence may vary and some may not be necessary.

Step 1: Size Up The Situation

As with any fire, first observe as many conditions as possible about the fire. The exact fire location may not be known. The majority of fires occur in the top ten feet of silage, and within this range, most occur in the top four to six feet. Fires often originate near the unloading doors where air leaks dry the silage, although a fire can start wherever the ensiled material is too dry. The first indication of a fire is often a burning or burned unloading door.

If considerable smoke is pouring out of the silo or silo chute, or embers are falling down the chute, the farmer should not enter the silo chute to examine the fire. Only a firefighter wearing full turnout gear and self-contained breathing apparatus (SCBA) should enter the chute.

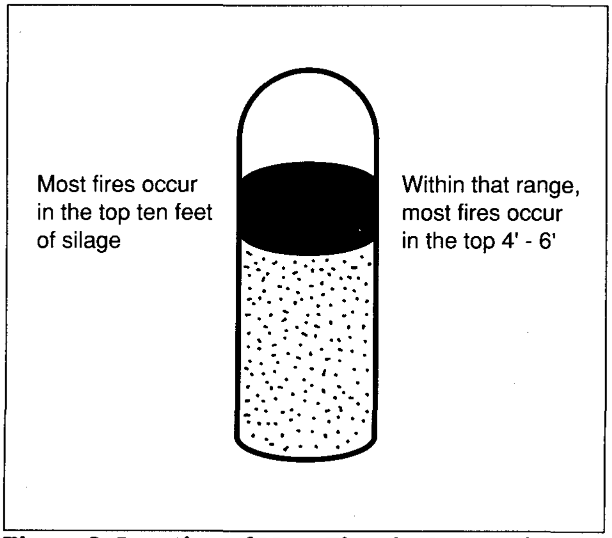


Figure 3. Location of Most Fires in Conventional Silos

After notifying the fire department, the farmer should attempt to close the bottom of the chute to prevent air movement through it until the fire department arrives. Air moving through the chute will fan the fire. Sheet metal or other non-combustible materials should be used to close the chute.

Remove all livestock from any exposed and adjacent buildings. Wet down the area around the silo chute to prevent fire spread. Place non-combustible shields (metal siding, etc.) over any openings to prevent sparks and embers from flying into barns and sheds.

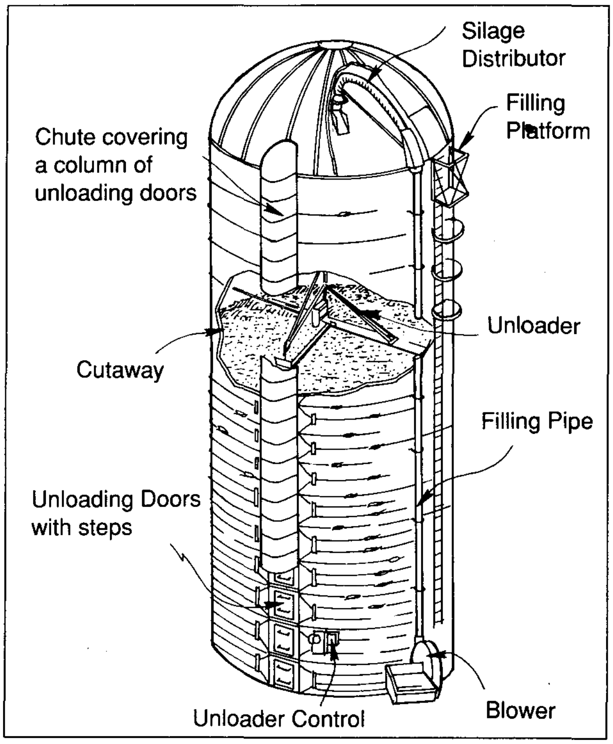


Figure 4. Typical Top-Unloading Conventional Silo

If only light puffs of smoke emit from the top of the silo, air movement up the silo chute may allow inspection and temperature checks without self-contained breathing apparatus. If continuous smoke or glowing embers are visible, the first person who climbs the chute to assess the situation should wear self-contained breathing apparatus.

Whether a fire is evident or just suspected, use a lifeline and do not step directly onto the silage. Lay wooden planks, large pieces of plywood, or ladders on the silage to distribute weight over a larger area and minimize the risk of falling into a burned out cavity.

Tie any person entering the silo with a lifeline attached as high as possible to a beam or silo hoop. Attach the line to a double bowline sling, a harness, or an upper "O" ring on the SCBA. Also, station a buddy in the silo chute to observe, assist, and maintain radio communication with the ground. Auxiliary lighting inside the silo is often needed; flood lights can be positioned from the filling platform.

Step 2: Knockdown of Surface Burning

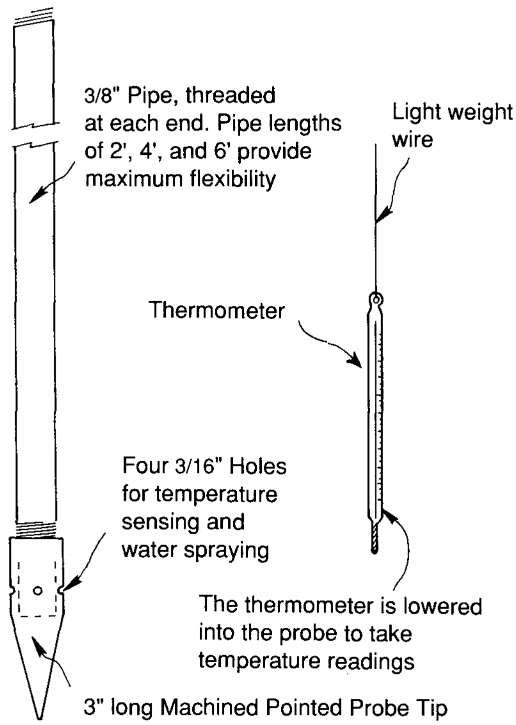
By the time the fire department arrives, the silo fire may have well-established flames. Unloading doors may have burned through, allowing flames to extend up the silo chute. As with any Class A fire, **douse** and **ventilate.** Water will cool the fire and keep flames from spreading.

Remove unloading doors and coverings so hot gases, smoke, and steam can escape. Dousing is effective only if water reaches the fire. One firefighter, in full turnout gear with lifeline, dousing from the silo blower platform or from the silo chute is usually sufficient to extinguish all surface burning. If the fire is below the top surface of the silage, water will not penetrate the silage, and injecting water through probes will be necessary (see Step 4).

Step 3: Temperature Readings

One of the keys to extinguishing a conventional silo fire is to find the exact fire location. This can be done with an easily constructed probe and a thermometer. Every fire department should have a probe and thermometers to locate hot spots in silage or hay (Figure 5).

Lower a thermometer or other temperature-sensing device on a lightweight wire into a probe to obtain temperature readings.
A variety of remote reading devices and temperature probes are available from various companies and may be used separately or in conjunction with the homemade probes. Dairy



ABOVE 180°F (82°C) — **DANGER**

140°F to 170°F (60 - 77°C) — **RECHECK in 2 hours**

BELOW 140°F (60°C) — **NO PROBLEM**

Figure 5. Probe and Thermometer

thermometers or other devices on the farm can be adapted for use in an emergency.

Make several temperature readings, starting near any obvious hot spots, and gradually moving toward the silo walls at three-foot intervals. If a fire is caught in its earliest stages, there may be only one hot area. However, several hot spots may exist because the fire will follow air pockets to support itself. Consequently, take several readings across the silage.

If temperature readings are near 180°F or higher, the material will eventually char, smolder, or burn. Temperature readings of 140°F to 170°F are not clear indications. Since heat moves slowly through silage and silo walls, the silage may be heating, or gaining or losing residual heat from another hot spot. Repeat the temperature readings every two or three hours to check for dangerous heating. Temperatures below 140°F indicate no particular heating problem.

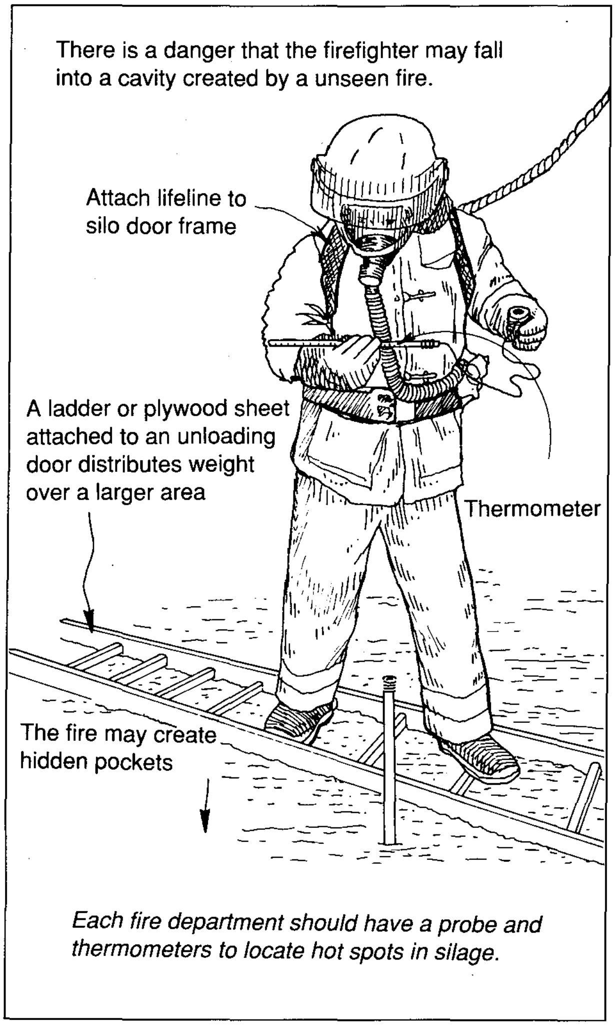


Figure 6. Probing for Hot Spots in Silage

How far a probe can be inserted into the silage depends on the condition of the silage. A probe will penetrate easily into a spot that has been charred or burned. On the other hand, it is difficult to push the probe more than four to six feet into packed, finely cut silage.

Infrared Detectors can detect hot spots in silos, but these do have limitations. Small, easy-to-use, and affordable infrared detectors have limitations as to temperature range, distance to the fire source, and the size of the hot spot. More sophisticated, complex, and accurate infrared detectors cost thousands of dollars and might be borrowed from insurance companies, industrial suppliers, or commercial firms that provide infrared detection services. Check possible sources for availability.

Step 4: Water Injection

Once the extent and location of the fire is established, inject water directly into the hot areas via the probe. Work slowly and methodically. Leave the injection probe in a single spot for several seconds to a few minutes before moving it (see Figure 7).

Because the holes in the perforated tip of the probe are only 3/16" in diameter, very little water is required. Therefore, use the smallest hose line from the fire engine. (Suggestion: attach the engine's smallest hose, usually 1 1/2", to the 3/8" probe by means of adaptors and a length of garden hose). In one instance, a garden hose attached to a 200-gallon farm sprayer tank was used to extinguish a fire.

In many cases, water may be injected from the silo chute, particularly when a hatch door has

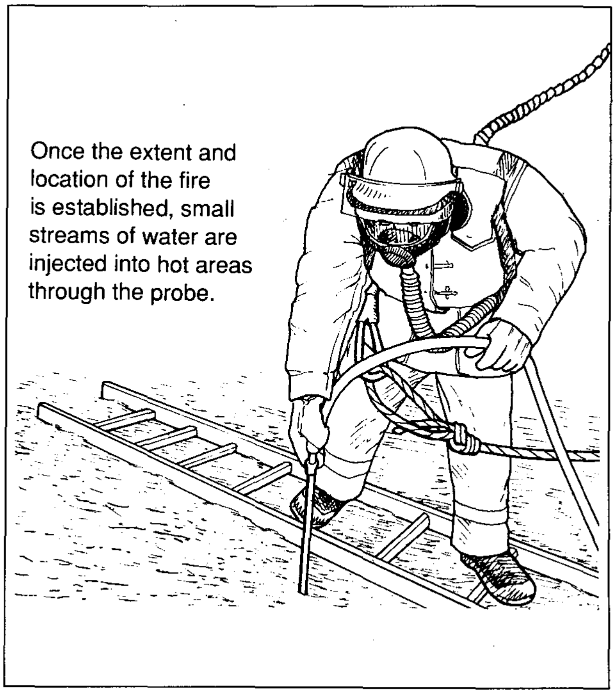


Figure 7. Water Injection

burned through. Considerable amounts of smoke and steam may blow back on the firefighter. Make sure that the firefighter is properly protected.

The firefighter operating the injection probe will require full turnout gear and lifeline. Station a second firefighter, also in full gear, inside the silo chute to help handle the hose and stand by for safety reasons. This is especially important if the probe operator goes inside the silo. In most cases, the probe operator will have to go inside the silo and inject water from the top down; however, this action must be judged at the fire scene.

A **water-gas explosion** caused by injecting water into burning silage is not a realistic concern in conventional silos. The few explosions that have been reported from silage fires have all been in oxygen-limiting silos where there was a build-up of explosive gases.

The water-gas reaction occurs when water molecules react with very hot carbon to form hydrogen and carbon monoxide. The reaction is highly endothermic (it absorbs heat), so the temperature of the material drops rapidly. Consequently, when water hits the hot silage, the instantaneous cooling effectively prevents the water-gas explosion.

For an explosion to occur, the right proportion of air (oxygen), an ignition source, and flammable gas (fuel) must be contained. This factor practically prevents explosions in conventional silos, where there is no containment of gases.

Water Additives. Fire in a silo does not change the characteristics of extinguishment chemicals that may be added to water, so chemicals that help water to absorb heat will work if used on a silo fire. If chemicals are mixed according to their labels, no adverse effects occur to the silage. Chemicals that reduce water friction are of no particular benefit because large quantities of water are not generally used in fighting silo fires.

Step 5: Unloading

Damaged silage must be unloaded because:

1. Overheated silage loses its nutritional value,
2. The top layers of wet silage may spoil, and
3. Any missed hot spots may reignite.

Heat Damage

Silage that has been heated over 150°F will lose much of its nutritional value. Charred silage also will have little feed value, since cows may not eat it, depending on taste or aroma. In some instances, cows actually will eat more heat-damaged silage to try to compensate for the lost nutritional value. The only conclusive determination of the quality of overheated silage is to have it tested at a forage laboratory. Silage below the fire level will not be damaged and will not lose any nutritional value.

Water Damage

Silage saturated with water may mold and spoil because much of the preserving acid produced during fermentation has leached out or been diluted. The nutritional value of the saturated silage is reduced, and the cows may refuse to eat it.

Reignition

When extinguishing conventional silo fires, it is possible to miss some hot spots. If spots are missed or only partially cooled, they can dry out and reignite. The injection of water tends to loosen silage fibers and create air spaces within the silage. If a hot spot is only partially extinguished, the extra air may help reignite the fire.

Unloading Precautions

As layers of silage are removed, take additional temperature readings and examine the silage to determine its condition. In most case histories, silage was unloaded to a level just below any burned or charred silage. Unloading below this level is necessary if there are hot spots, fire-damaged silage, or water-saturated silage.

Most silo unloader motors are designed for intermittent operation and will overheat if run continuously. Hot silage may flame up and burn the motor as layers are exposed to the air. Allow the unloader motor to cool off every half hour and probe for hot spots to prevent these problems.

ADVANCED BURNING FIRES IN CONVENTIONAL SILOS

Some silo fires are not discovered until several weeks after their ignition. A silo fire in its advanced stages rarely remains below the surface of the silage. Instead, the fire travels horizontally towards the walls of the silo or vertically to the upper surface of the silage.

Silage shrinks as it dries. As a result, there may be an air space several inches wide between the silage and the silo wall. When silage is exposed to the air, it dries and becomes an excellent fuel for fire. Quite often, the unloading doors in a conventional silo leak air and permit the silage to dry and shrink for some distance down the silo. This drying produces a column of dry fuel along the doors.

When fire reaches any of these areas of dry silage and abundant air supply, it spreads very quickly and burns freely instead of smoldering. Extinguish the surface fire **before** attacking the subsurface fire.

In a silo fire, a straight-tip nozzle is more effective than a fog nozzle. The water stream from a straight-tip nozzle penetrates the pile and better extinguishes fire that has become deep-seated. A 3/8" tip is recommended. After the surface fire is extinguished, the procedures for extinguishing a subsurface fire are employed.

Types Of Advanced Burning Fires

Fire Along The Unloading Doors. The most common example of advanced burning is a silo fire along the column of dry silage behind the unloading doors (see Figure 8). Attack these fires in the following manner:

1. Follow recommended safety practices, including the wearing of SCBA and full turnout gear.

2. Extinguish all surface burning by aiming a straight-tip nozzle through burned-out openings in the unloading doors. Usually, these doors will allow access to the fire. Chopping through a door that is not burned will be difficult and probably unnecessary.

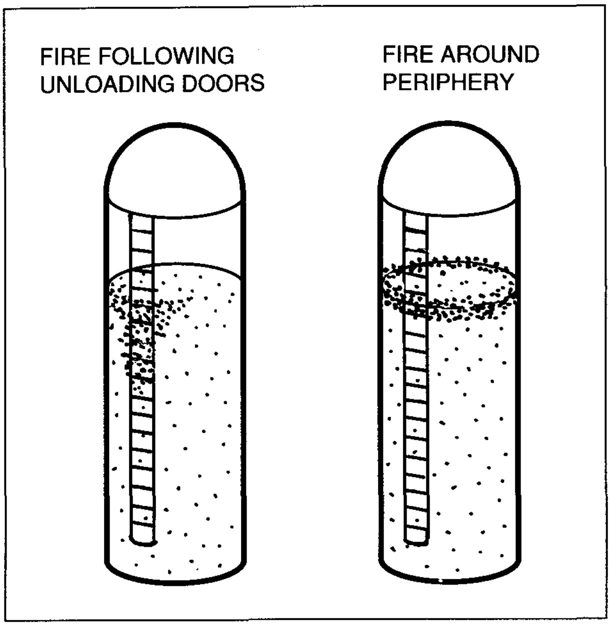


Figure 8. Typical Advanced Burning Silo Fires

3. Extinguish all subsurface fire using short temperature and water probes. Insert them in the silage in all directions by passing them through the burned-out door openings (Steps 3 and 4, pp. 5-6).

After all fire is extinguished, replace burned doors with new or rebuilt ones. Backfill dampened silage into the burned-out cavities and level the top surface of the pile so the farmer can immediately begin the unloading process (Step 5, p. 7).

Fire In A Horizontal Pattern. The next most common example is a fire burning in a circular pattern horizontally around the inside of the silo wall. The burn pattern is usually a trench-like burned area only three to four feet deep around the silo (Figure 8). Attack these fires in the following manner:

1. Extinguish all surface burning using a straight-tip nozzle. Start the knockdown just inside the nearest unloading door, advancing halfway around the ring. Retrace the path and work around the other half of the ring to the far side of the silo. Lay planks to walk on, wear SCBA and full turnout gear, and use lifelines.

2. Extinguish all subsurface fire using temperature and water probes (Steps 3 & 4).

OTHER CONCERNS

Structural Damage

In most silo fires there is little, if any, structural damage. If fires are allowed to rage out of control, concrete may crack, but this is not the normal case. Slow-burning fires seldom damage concrete, but they may damage or weaken a concrete plaster interior coating, particularly near unloading doors where the temperature is very high.

Silo manufacturers do not recommend applying a water fog to the outside of a silo. Less stress is placed on the heated silo wall by allowing it to cool down naturally than by artificially cooling it with water. In other words, applying cool water to heated concrete may cause more damage to the silo wall than the heat alone. There is no danger of structural collapse, even in small areas that become so overheated that they glow.

After a silo fire, inspect and repair the silo as needed. The silo dealer or manufacturer and insurance carrier may be able to assist you.

Fires Outside The Silo

There is some question as to whether an external fire in a nearby barn can cause silage inside a silo to ignite. This can happen with a large fire, but silos and the silage inside can be saved in many instances, even when the entire barn is lost. Outside heat is not readily transferred to the silage inside a silo.

The Uses Of Gases

Carbon dioxide or liquid nitrogen may help extinguish some conventional silo fires. Both gases displace oxygen that supports the fire, so the fire suffocates. The expense of the materials and cold weather problems, however, make the water injection method a more practical extinguishing technique.

If gas is used, carbon dioxide is the usual choice because it is more readily available than liquid nitrogen. Gases may be injected into the silage with a probe pushed through burned-out hatch doors, holes cut into hatch doors, or holes in the side wall.

After carbon dioxide (CO_2) or nitrogen (N_2) have been used to extinguish a silage fire, certain procedures must be followed in order to prevent reignition. The cause of the initial fire probably was the filling of the silo with silage that had a moisture content of between 25% and 45% (see Table 3 and supporting text on page 12). The heat of the fire further dried the silage around it; making additional fuel for the fire.

After the fire is extinguished using CO_2 or N_2, frequent monitoring of the silage must be made twice daily, especially near the fire area. This monitoring should continue for 2-3 weeks or until the temperature of the silage stays well in the "safe" range of 100°-140°F for several days.

If the temperature rises, sufficient O_2 and dry material are present to support additional burning and the silo should then be recharged with CO_2 or N_2. The best fire control will occur when the silo is frequently charged with CO_2 or N_2. These gases reduce O_2 concentration in the silage so that it is below the amount required for combustion to occur. Temperature monitoring must continue.

If the fire continues to burn and the temperatures continue to rise after the three week period, the silage will have to be removed from the silo. A fire watch should be stationed at the unloading chute to extinguish any burning material and wet down any charred or extremely dry material being unloaded. The unloaded silage should be taken to a remote spot in case it reignites at a later time.

FIRES IN OXYGEN-LIMITING SILOS

A spontaneous combustion fire in an oxygen-limiting or sealed silo is rare, but can occur with improper management. The basic rule for proper maintenance of these silos is to keep all openings closed, except when filling the silo or operating the unloader. Excluding air preserves the silage as well as prevents combustion. Even with silage at 55% dry matter, there is usually insufficient oxygen to support a fire after an oxygen-limiting silo has been filled and tightly closed. Sometimes a slow-charring fire will self-extinguish due to insufficient oxygen.

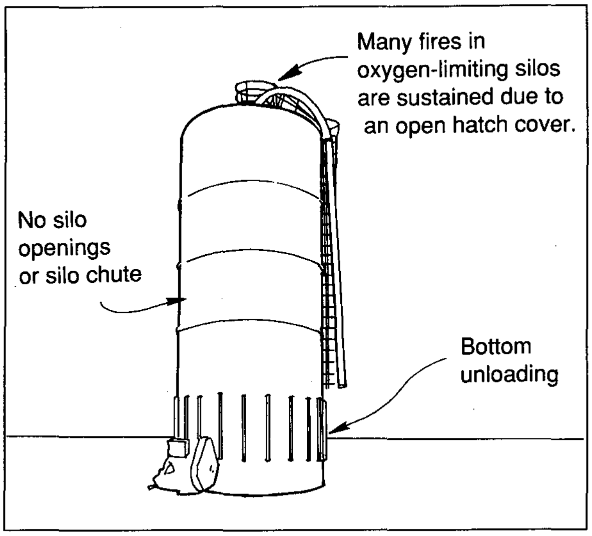


Figure 9. Oxygen-Limiting or "Sealed" Silos

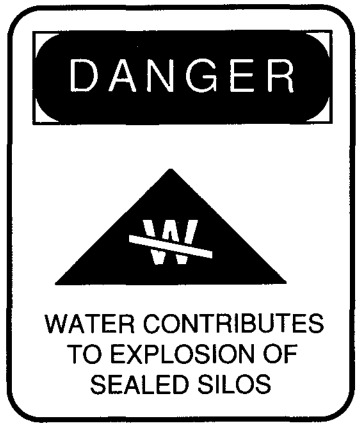
Despite these factors, there have been a few disastrous explosions in oxygen-limiting silo fires. In 1985, four firefighters were killed and another seriously injured in silo explosions in Indiana, Louisiana, Ohio, and Pennsylvania. A fire in an oxygen-limiting silo is potentially hazardous, and proper methods or techniques for extinguishing these fires can prevent explosions. With sufficient heat or flame to ignite the confined gases, the only thing preventing an explosion is insufficient oxygen.

CONTROL OF FIRES IN OXYGEN-LIMITING SILOS

Do nothing to increase the level of oxygen or air inside the silo. Opening the top hatch cover to dump water or foam inside can create an explosive mixture. Air entrapped in water droplets and foam particles can increase the danger. **Do not use water on fires in oxygen-limiting silos.**

Signs should be placed at the base of the silo adjacent to the silo ladder and at the top of the silo near the closest roof hatch door opening. These signs warn firefighters and other emergency personnel of the dangers of using water to extinguish an oxygen-limiting (sealed) silo fire.

An oxygen-limiting silo always has some oxygen inside. Air and oxygen will be found in the dome above the bottom unloader and between the top of the silage and the silo roof. There may be other air leaks through the silo walls because of weather stress, defective materials, or poor workmanship. Many oxygen-limiting silo fires start or are sustained because the farmer has neglected to close the top hatch cover after filling or the unloader door after unloading.



These signs are available for $4.25 each from the Pennsylvania Agricultural Safety Council 204 Agricultural Engineering Building University Park, PA 16802.

Figure 10. Warning Sign for Sealed Silos

Fires in sealed silos are discovered when burned or burning silage comes out the bottom unloader or when smoke escapes from the top of the silo. First, the opening or hatch at the outlet of the unloader should be sealed. Second, openings such as manhole covers and drain caps used for silo maintenance should be checked and sealed.

If the silo is cold, quiet, and emits little or no smoke, carefully climb the silo and close any open hatch covers on the roof, but **do not lock or latch the cover.** Closing the hatch prevents air intake. If gas pressure increases above the relief capacity of the breather valve, the hatch must be able to lift and relieve the pressure.

Leave the silo closed for one to three weeks, until the fire consumes all the oxygen in the silo and self-extinguishes. During this time, make weekly temperature checks of samples from the unloader to be sure the fire is out.

Leave an open roof hatch alone if considerable smoke or steam is escaping or if the silo is shaking or rumbling. Closing the hatch on an active fire may bring carbon monoxide and air mixtures into their explosive range.

If sealing the silo does not extinguish the fire, inject liquid nitrogen or carbon dioxide to displace the oxygen and cool the fire. Be careful not to introduce additional oxygen. Most silos have a pipe nipple used to inject gases for fire control. Oxygen-limiting silos should be inspected each year to determine whether the nipple is open and functional. If a nipple is not present, have the farmer install one or have one installed by the manufacturer or dealer.

To Inject Gas In A Sealed Silo: [1]

1. Remove the cap from the pipe nipple.

2. Connect reducers, bushings, nipples, shut-off valve, unions, and a 90 elbow as required to connect the silo nipple with the appropriate gas regulator using a number 88 hose.

3. For nitrogen, use an 8-580 or an IL-580 regulator; for carbon dioxide, use an 8-320 or an IL-320 regulator.

4. Set the regulator at 40 psi. Open all valves and flow gas into the silo.

Liquid nitrogen and carbon dioxide cylinders are available in many industrial areas. The estimated amounts of carbon dioxide and liquid nitrogen needed to control silage fires are listed in Table 2.

Depending on the quantity and quality of the silage that remains, the silo may need to be emptied after the fire has cooled. If a small amount of poor quality silage remains, the fire may reignite when the control gases escape.

[1] Adapted from *Fighting Fires in Harvestore Structures* by A. O. Smith, Harvestore Products, Inc.

Table 2. Estimated Amounts of Carbon Dioxide or Liquid Nitrogen Needed to Control Silo Fires

Silo Size	Carbon Dioxide (CO_2)	Liquid Nitrogen (N_2)
20 x 60	20 Cylinders *	40 Cylinders
20 x 70	22 Cylinders	44 Cylinders
20 x 80	30 Cylinders	60 Cylinders
24 x 60	30 Cylinders	60 Cylinders
24 x 70	35 Cylinders	70 Cylinders
24 x 80	40 Cylinders	80 Cylinders
30 x 60	45 Cylinders	90 Cylinders
30 x 70	50 Cylinders	100 Cylinders
30 x 80	60 Cylinders	120 Cylinders

*50 lb. cylinders

The fire is not likely to restart if a large amount of good quality silage remains.

A four-page bulletin, *Fighting Fires in Harvestore Structures*, developed by A.O. Smith Harvestore Products, Inc., gives step-by-step instructions for putting out fires in their silos. The procedures outlined in their bulletin are applicable, with slight variation, to other makes of oxygen-limiting silos. If a fire should occur in an oxygen-limiting silo, call the appropriate dealer immediately.

SAFETY PROCEDURES FOR OXYGEN-LIMITING SILOS

There are many safety procedures to follow when working near an oxygen-limiting silo. Manufacturers are constantly warning farmers and firefighters to stay out of a filled or partially filled oxygen-limiting silo. **There is not enough air to support life.**

Respiration and fermentation of the material in an oxygen-limiting silo converts oxygen in the air into carbon dioxide. Within thirty minutes after forage or high moisture grain is put into a silo, the oxygen level may be too low for a person to breathe. If tools or other objects are accidentally dropped into the structure, **do not** attempt to retrieve them without the use of oxygen apparatus.

WHAT CAUSES SILO FIRES ?

Plant material continues to respire or "breathe" for a short time after it is cut. After a silo is filled, aerobic respiration produces heat until the oxygen in the pile is consumed, then anaerobic fermentation produces heat and preservative acids until the chopped forage becomes stable, or ensiled.

If forage is stored at the recommended moisture content, the water in the forage conducts heat away from the silage mass and overheating will not occur. If forage is too dry, heat cannot be dissipated quickly enough and the internal temperature rises until spontaneous combustion occurs.

Table 3. Characteristics of Stored Silage or Hay by Percentage of Moisture and Dry Matter.

DRY MATTER	MOISTURE CONTENT	
15	85	
20	80	Silo Leaks
25	75	
30	70	Undesirable Fermentation
35	65	
40	60	GOOD SILAGE RANGE
45	55	
50	50	
55	45	
60	40	**DANGER ZONE:** Fire Hazard in Silo or Hay Mow
65	35	
70	30	
75	25	
80	20	Good Hay Range

As the temperature rises above 130°F, a chemical reaction occurs which may sustain itself. Heat kills microorganisms at 250°-400°F and begins to break down the forage by a trapped oxidation process known as pyrolysis. As pyrolysis continues, oxygen within the silage supports the smoldering fire. If the surrounding silage cannot support combustion, the fire may die, leaving a charred cavity. More frequently, the fire will slowly spread until it reaches the surface by burning through wooden doors.

ELEMENTS OF GOOD SILAGE [2]

To make top-quality, low-moisture, haycrop silage with the minimum possibility of a silo fire:

1. Chop haycrop between 45% and 65% moisture. Test the moisture of the forage being ensiled.
2. Chop grass silage fine (1/4" theoretical cut) so that the actual length is not over 1/2" to 1". If 10% of the chopped forage is over 1 1/2" in length, sharpen knives and reset the shear bar clearance.
3. Chop alfalfa silage in the bud stage and grass in the boot stage.
4. Mow and condition only what can be put up in a single day.
5. Keep silo walls sealed, smooth, and solid.
6. Check the condition and seal of all silo doors. Seal old doors with sealant on the lip of the door frame.
7. Use a good center fill or properly adjusted mechanical silage distributor and follow manufacturer's instructions.
8. For low moisture silage, seal all drains before filling.
9. Do not ensile frozen alfalfa.
10. Fill the silo rapidly (at least 2' per hour) to assure good packing.
11. Empty the silo at least once every two years to stop any slow heating due to small air leaks.
12. Inspect the empty silo and consult with the silo manufacturer about maintenance and repairs.

[2] Adapted from *International Silo Association Manual*

SUGGESTED READING

Farm Accident Rescue. 1986. Baker, L. Dale, William E. Field, Rollin Schnieder, Clair W. Young, Robert A. Parsons, and Dennis J. Murphy. NRAES-10. 35 pp.

Fires in Agricultural Chemicals. NRAES FS-30.

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