Hay & Silage Fires

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Lives have been lost and hay crops destroyed because spontaneous combustion has caused fires in silos and hay mows. Alfalfa-grass mixtures are most often involved, but other material such as corn stover, peanut hulls, dried brewer's grain, etc. can also be consumed by spontaneous combustion. How does spontaneous combustion occur and how can it be prevented?

The Heating Process

Plant material continues to "breathe" for a short time after cutting. This respiration produces some heat in orage. Then, everpresent organisms, in the process producing acids necessary to ensile the material in a silo, produce heat as well. If the material is wet, the water in the forage conducts the heat from the mass and spontaneous combustion will not occur. If the material is dry-below 20%-the micro-organisms are relatively inactive, so little heat is produced and spontaneous combustion will not occur.

A hay crop that is placed too wet (above 25% moisture) into a mow or too dry (below 40% moisture) into a silo will rapidly heat. If the mow or silo is so large that heat loss is restricted, the internal temperature will rise. As the temperature rises above 130°F, a chemical reaction called the Maillard Reaction occurs and may sustain itself. The heat kills the micro-organisms at 250° to 400°F and begins to break down the hay crop by a chemical reaction called pyrolysis. The Maillard Reaction does not require oxygen, but the flammable gases produced by pyrolysis are at a temperature above their ignition point. These gases will ignite when they come in contact with oxygen.

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Fire Prevention in Silos

Spontaneous combustion is not an accident; it is a gambling loss. The hay was either harvested too wet or the silage too dry. By using good storage practices, not only will spontaneous combustion be avoided, but a higher quality hay or haylage will be obtained.

The following elements are necessary to make good silage and to prevent fires.

A tight silo. The doors and walls of a tower silo must be closed and tight to keep out oxygen.

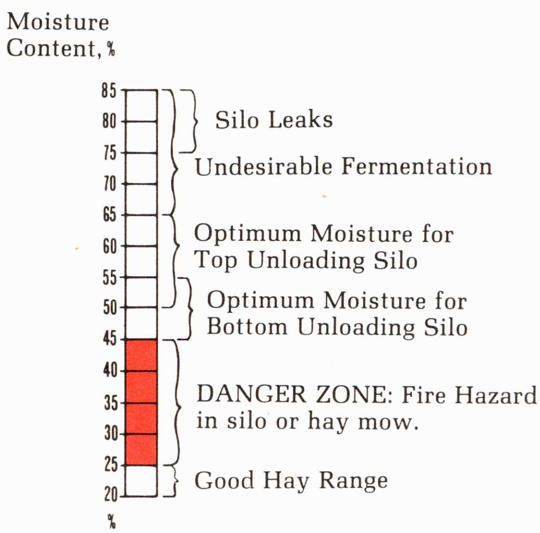
Moisture content. Most silo fires occur because the ensiling material is put into the silo too dry. The hay crop should be 50% to 65% moisture for a top unloading tower silo and 45% to 55% for a bottom unloading tower silo. Warranties for some bottom unloaders are void if haylage is above 50% moisture. Undesirable fermentation occurs above 65% moisture. A crop below 45% moisture, coupled with extra oxygen from poor packing or leakage of oxygen into the silo, risks heat damage or fire.

Length of Cut. The length of cut should be 3/8″ to 1/4″. The short length aids packing as well as unloading.

Distribution. A distributor should be used to insure adequate packing along the silo walls.

Filling rate. The filling rate should be rapid for good packing — a minimum of 2 feet per hour.

Characteristics of Stored Silage or Hay by Moisture Content



Silo Fire Control

Fighting a silo fire is a very frustrating experience that can be extremely dangerous. These persistent fires require special fire fighting techniques that may not always work. But regardless of what type of material is ensiled, the problems and hazards of fire extinguishment are the same.

Oxygen Availability

Generally, more fires occur in open-top silos than in air-tight models because more oxygen is available to support the fire. Most fires originate near the hatch doors because of air leaks, although a fire can occur at any point where material is too dry. The burning through of a hatch door is often the first indication of a fire. Of course, more oxygen is available to support the fire once a door burns through.

Considerable evidence indicates that air-tight silos are not strictly oxygen free, but "oxygen-limiting" instead. Oxygen-limiting silos may also develop leaks due to weather stresses or poor construction. In addition, as silage is unloaded by the bottom unloader, a dome-shaped cavity is created which causes an air exchange with each running of the unloader. The first indication that an oxygen-limiting silo is on fire is smoke escaping through the top of the silo, or silage glowing or bursting into flame as it is unloaded.

The Problem With Water

Using water on any silo fire is often ineffective, ma damage the silo structure and, with oxygen-limiti types, may cause an explosion. It is difficult to ge enough water to hot spots in the silage because it follows the path of least resistance and often never hits the right spot. Air entrained in the water allows even more oxygen to reach the hot spots.

Attempts to cool the walls of silos with water have practically no effect on the temperature of the silage and may damage the silo structure. Sudden temperature change puts additional stress on the silo walls and may cause them to crack. Most oxygen-limiting silos are glass lined and are especially susceptible to this problem.

The most dangerous problem, is that of creating a "water gas" reaction. Water that is added to very hot carbon material (which burning silage is) forms carbon monoxide and hydrogen, both of which are extremely flammable. These gases can collect at the top of an oxygen-limiting silo and may be ignited by burning material and additional oxygen. The explosive gases can also be trapped in conventional silos that have roof panels or other coverings spread across the top. There should be no collection of explosiv gases if there are no panels or coverings whatever.

Attempts to unload smoldering or hot silage cause mixed results. Most unloader motors are designed for intermittent operation and they will overheat if run continuously. Also air movement created by the running unloader increases the temperature of the silage, causing the fire to spread faster. Top unloaders are also likely to burn during unloading because the hot material often bursts into flame when it is exposed to additional air.

A silo fire will be well developed before it is discovered.

Control or Extinguishment

Dry ice and liquid nitrogen are two relatively effective and safe substances which can be used to control silo fires. Dry ice or carbon dioxide in its gaseous form is heavier than air; thus it must be placed on top of the silage. As it turns into vapor, the CO_2 disperses through the silage, replaces the oxygen, and allows the silage to cool. This method of silo fire control shou only be used on an open-top silo where no explosi gases collect. The one danger in this method is that there is usually no way to tell what kind of cavity the fire has created below the surface. Therefore, it is ‹tremely important that no one step directly on the lage as it could collapse.

Liquid nitrogen in its gaseous form is lighter than air, so it should be injected beneath the hot spot. It too, displaces the oxygen to cool the fire. A small hole, drilled in the silo wall, and a tube or probe, hooked to the gas line, will allow the nitrogen to enter the silo. Care must be taken to insure that additional oxygen is not pulled into the silo by this process. This method can be used with both open and oxygen-limiting type silos.

As a rule, stay off the tops of oxygen-limiting silos. Even the slightest action, such as opening the top hatch cover, may detonate explosive gases that may have collected. Leave an open roof hatch alone if there is any smoke or steam coming out the top, or if the silo is shaking or rumbling. If the silo is quiet and there has been no visible smoke for several hours, it should be safe to close the top hatch cover. Do not tie the cover down, though. If gas pressure subsequently builds up, beyond the relief capacity of the breather valve, the cover can lift to relieve the pressure.

tay away from the top of a burning silo!

While dry ice and liquid nitrogen can help control silage fires, the original cause of the fire — dry material — still remains. If there was enough air leakage to support a fire in the first place, it is likely that there will be enough leakage to allow the control gases to escape. Additional oxygen can then get into the silo and reignite any dry material that is left. For this reason it is best to remove the dry silage while it is somewhat cool. Unloaded silage should immediately be taken to a remote spot in case it bursts into flame.

The estimated amounts of dry ice and liquid nitrogen needed for control of silage fires are listed in the following table.

SILO SIZE (Feet)	POUNDS of CO_2 (Dry Ice)	POUNDS of N_2 (Liquid Nitrogen)
12 × 30	140	90
14 × 40	250	160
16 × 50	400	250
20 × 50	600	400
30 × 50	1400	900

Tractor exhaust fumes or tanks of carbon dioxide are sometimes used as extinguishers, but the dry ice and liquid nitrogen methods appear to combine the elements of effectiveness, safety, and practicality most ideally. Liquid nitrogen or dry ice may not be immediately available in all areas. But it may take a silo a month or more to burn itself out, so a few days wait is not unreasonable. Liquid nitrogen and dry ice can be found in many industrial areas and near larger metropolitan areas.

Keep in mind that once a large cavity is formed, or several hatch doors have burned through, there may be no way to extinguish the fire. All methods of extinguishment or control are contingent upon stopping the oxygen supply. Consequently, there are times when it is cheaper, safer, and more practical to let the silage burn. This is certainly a frustrating decision to have to make, but it is an option that should not be overlooked.

Sometimes it is cheaper, safer, and more practical to let a silo fire burn.

Fire Prevention in Hay Mows

There will be no danger of spontaneous combustion if the hay crop is put into the mow below 25% moisture — 20% is better.

Probing a Hay Mow

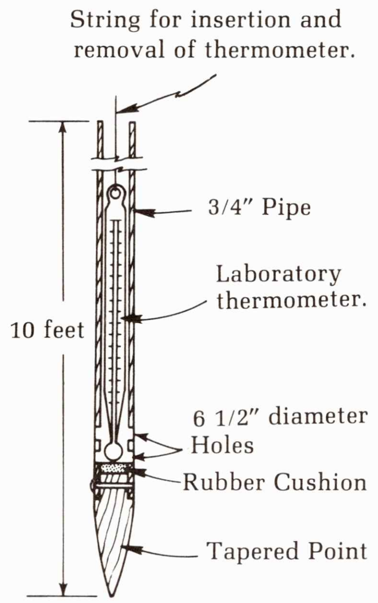
As a precaution, hay can be probed regularly with a thermometer attached to a rod. If the temperature reaches 150°F, a chemical reaction will likely continue the heat generation process. A fire may be prevented because a probe is used.

Chemical Additives

Additives are sometimes used to treat damp hay before placing it in the mow, but are not necessary for a hay crop going into the silo as it will ensile properly if harvested within the correct moisture range.

Salt (sodium chloride) sprinkled on hay as it is stored will not prevent spontaneous combustion. Heating was not prevented in an experiment where 1 1/2 percent (by weight) of salt was added to long alfalfa hay averaging 35 percent moisture. In fact, salted hay reached a temperature of 135°F (57.2°C) while the unsalted hay peaked at 134°F (56.7°C). Both peak temperatures occurred during the first week of storage.

HAY MOW PROBE



150°F (65°C) ENTERING THE DANGER ZONE. Temperature observations should be made daily.

160°F (70°C) DANGER! Temperature observations and mow inspections should be made every four hours.

175°F (80°C) HOT SPOTS OR FIRE POCKETS MAY BE ANTICIPATED. Stop all ventilation. Call the Fire Department for stand-by service.

185°F (85°C) REMOVE THE HOT HAY. A fire department pumper with an ample supply of water should be ready to quench any flames which might develop when air comes into contact with the hay being removed. Hot and charred hay should be deposited at a safe distance from the buildings in the event that flames redevelop.

212°F (100°C) CRITICAL! Temperature rise is rapid above this point and the hay ignition point will be quickly reached. Wetting to cool the mow is advisable before hay removal.

Adapted from the Vermont Extension Service

Hay treated with chemical preservatives containing ethoxyquin and BHT (butylated hydroxytoluene) will, at around 240°F, produce a hydrogen cyanide gas. Extreme caution must be taken when fighting a hay fire using these chemicals since hydrogen cyanide is very deadly. Additives such as "Hay Savor", "ChemStor" or "Propcorn", contain primarily propionic acid and do not produce hydrogen cyanide during a fire.

To simplify information, trade names have been used in this publication. No endorsement of named products is intended nor is criticism implied of similar products which are not named.

References

Bruhn, H.D., "Preliminary Notes on Silo Fires and Control Procedures". Dept. of Ag. Eng. Mimeo, University of Wisconsin, July 1976.

Bruhn, H.D., Jensen, D.V. and Koegel, R.G., "Prevent Hay Mow and Silo Fires". University of Wisconsin Pamphlet A2805, June 1976.

Campbell, J.K. "Who wants a 20'× 60'fireplace?" *Hoard's Dairyman*, Vol. 118, No. 10, pg. 677, 684. May 23, 1973.

Drum, Donald A. and Rappleyea, Paul, "Treated Hay Can Release Hydrogen Cyanide in Fire". *Fire Engineering*, June 1977.

Koegel, Richard G. and Bruhn, H.D. "Inherent Causes of Spontaneous Ignition in Silos". ASAE Paper 60-164, June 1969.

Roethe, Harry E. "Spontaneous Heating and Ignition of Hay". *Agricultural Engineering*, April 1933 and December 1937.

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