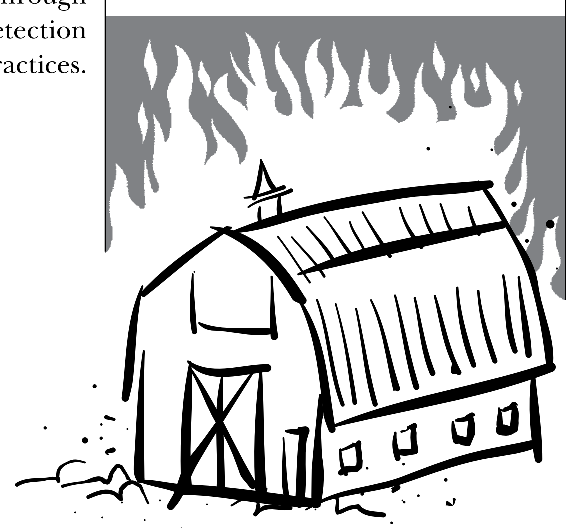
Fire Safety in Horse Stables

Many of us know the legend of Catherine O'Leary's infamous cow accused of kicking over a lantern and starting a barn fire on the night of October 8, 1871, leveling three square miles of Chicago. A barn fire in today's world is not likely to destroy a city, although it is likely to devastate the barn. In the blink of an eye, a fire can destroy a barn structure and all its occupants, while the owners stand by helplessly. Many advances in residential fire protection have been made, but protecting barns is much more difficult because of their harsh environment and housing requirements of the horses in them.

In barn fires, the old adage "an ounce of prevention is worth a pound of cure" could not be more true. Planning is the greatest asset in fire prevention. This bulletin provides an understanding of fire behavior and how fire and fire damage can be minimized or prevented through building techniques, fire detection options, and management practices.

How a Fire Behaves

A fire occurs when a fuel source comes in contact with an ignition source. A fuel source can be any item that contains wood, plant material, plastic, paper, fabric, combustible fuel, etc. After contact with the ignition source (anything that would cause the fuel to burn, e.g., spark, intense heat), the fuel starts to smolder. Oxygen availability, fuel type, and physical arrangement are factors that determine the length of the smoldering process. Smoldering can vary from minutes to hours. Fires caught during this stage have the greatest chances of being controlled with minimal damage, but are still extremely dangerous. Smoldering fires may also be difficult to detect and completely extinguish, especially with smoldering hay or wood shavings, when the fuel itself helps



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PennState Extension

Fire Prevention Is the Best Protection

There is no such thing as a fireproof building, especially in agricultural settings. Building design, management, and safety practices are the best way to minimize the risk of fires. It has been estimated that the root cause of 95% of preventable horse barn fires is from careless smoking, with faulty electrical systems high on the list. Fires can grow quickly and give no warning. In most cases, if you see flames, it is already too late. The damage a fire causes grows exponentially with the amount of time it has burned. Fire is extremely dangerous at any stage of growth and controlling it is best left up to the professionals.

Most barn fires occur in the winter when most forage and bedding is stored, electrical use is high, and equipment repairs and upgrades are traditionally made. Most of the components in a horse barn are highly flammable. Stall walls are frequently constructed with wood and horses are usually standing in ample amounts of dried bedding, eating dried forages.

to insulate the fire and prevent water penetration. The time it takes a fire to grow and spread is again related to a number of factors, such as the fuel source, the fire temperature, and the time the fire has to burn.

Smoke and heat production increase as the fire smolders. By the end of this smoldering or "incipient" phase, enough heat has been generated to produce flames. Once flames are present, the fire is extremely dangerous and unpredictable. It grows rapidly and the heat produced becomes intense. The capabilities of fire extinguishers as a line of defense will soon be surpassed. After flame eruption it only takes a few minutes for ceiling temperatures to exceed 1,800°F. As ceiling temperatures continue to rise, the building acts as a boiler and the "flash point" is soon reached. When fire has reached the flash point, often in as little as 3 to 5 minutes, the hot air temperature simultaneously ignites all combustibles within the space. At flash point, survival within the structure is unlikely, and the building contents are destroyed.

Smoke is produced in the earliest stages of fire development. The color and density of the smoke is dependent on fuel and burning conditions. Low-temperature fires produce more visible smoke particles, creating darker, thicker smoke, whereas hotter fires have smaller particles in the smoke, making it less visible. Smoke and heat are the fire's killing attributes. Smoke contains noxious gases and vapors specific to the fuel. The most common products of combustion (fire) are carbon monoxide and carbon dioxide. As the fire consumes the available oxygen in the room, it releases carbon monoxide. When inhaled, carbon monoxide combines with blood hemoglobin more readily than oxygen would, resulting in suffocation, even if an adequate supply of oxygen is available. Elevated levels of carbon monoxide and carbon dioxide increase respiration in an attempt to obtain more oxygen, resulting in the inhalation of more deadly gases. The consequences are swift thorough incapacitation and asphyxiation. Bodily harm from smoke is increased by its intense heat. When this super-heated mass of gases is inhaled, the respiratory tract will be seared. Smoke damage can occur even before flames are visible.

Once all available fuel sources have been used, the fire will "burn out." Unfortunately, this is not necessarily the end of the fire. Barns and agricultural buildings often contain large quantities of fuel sources that can be impervious to water (e.g., hay, petroleum fuels, and fertilizers). It is common for some of these fuel sources to remain unburned during the initial fire, then continue to smolder. These smoldering pockets often re-ignite or "re-kindle" another fire, requiring another visit from the fire department.

Hay Fires

Hay fires are unique to the horse and agricultural industry. Baled hay can be its own fuel and ignition source. The majority of hay fires occur within 6 weeks of baling, usually caused by excessive moisture in the bale. Ideal moisture range for hay at baling is 15 to 18 percent. Even after grass and legume forages are harvested, plant respiration continues and generates a small amount of heat. In properly harvested forages, respiration decreases and will eventually cease during drying and curing. The heat of respiration is normal and under appropriate curing is inconsequential. However, if moisture levels are too high, the respiratory heat will provide an environment suitable for the already-present mesophilic microorganisms (that require moderately warm temperatures) to grow and multiply. As these microorganisms grow, heat is produced as a byproduct of their respiration and reproduction. Once the bale interior reaches temperatures of 130 to 140°F, the environment becomes unsuitable for these organisms and most die. If microorganism activity declines, the interior bale temperature also declines. This cycle may be repeated several times, but the maximum temperature will be lower each time. Hay that has sustained these heat cycles has lost its quality as a feeding source, but poses no threat as an ignition source.

Baled hay becomes a potential fire hazard when the interior bale temperature does not cool after the first heating cycle. If conditions are favorable, the heat created by the mesophilic organisms provides an environment for thermophilic, or heat-loving, microorganisms to take over. When the thermophilic microorganisms begin to multiply, their heat of respiration can raise the interior bale temperature to 170°F before they die from the heat. This is an extremely high temperature and can cause the bale to ignite if oxygen is present. The growth of microorganisms within the hay bale creates a microscopic cavernous environment, similar to a sponge. The damaged material in the bale combines readily with oxygen and, in its already-heated state, can self-ignite quickly. A burning bale of hay may be difficult to detect because the inside of the bale burns first. Hay fires are very difficult to extinguish completely. The tightly laced forages prevent water from penetrating to the core. Only a forceful blast of water can penetrate deep enough to extinguish the fire.

Hay temperature monitoring can be done to ensure that bale temperatures never reach critical levels. Under less-than-ideal field curing conditions, hay may have been baled above the recommended 15 to 18 percent moisture level. Check newly baled hay twice a day for heat buildup.

A temperature probe is available at most farm supply companies (e.g., Nasco, Gemplers) and stores (Agway) from $12 to $20. If bale temperatures have reached 150°F, monitor the interior bale temperature frequently, as the temperature is most likely to climb. By the time the interior bale temperature reaches 175 to 190°F, a fire is about to occur, and at 200°F, a fire has already erupted (Table 1).

An alternative to purchasing a temperature probe is to make one, using a metal rod ⅜ to ½ inches in diameter (Ogburn 1995). Drive the rod into the hay and let it stand for at least 15 to 20 minutes before removing it. If the temperature within the bale is less than 130°F, you should be able to hold the metal comfortably in your bare hand. If the bale has reached a temperature of 160°F or greater, the rod will be too hot to hold comfortably in your bare hands. If the rod is too hot, let it cool for a few minutes and then reconfirm by taking another sample. When hot hay bales are found, summon the fire department. Be sure to tell the dispatcher that you have hot hay bales that may ignite instead of saying that you have a hay fire. This will help the fire company in planning on how to deal with your situation.

Table 1. Determining Hay Temperatures with a Probe

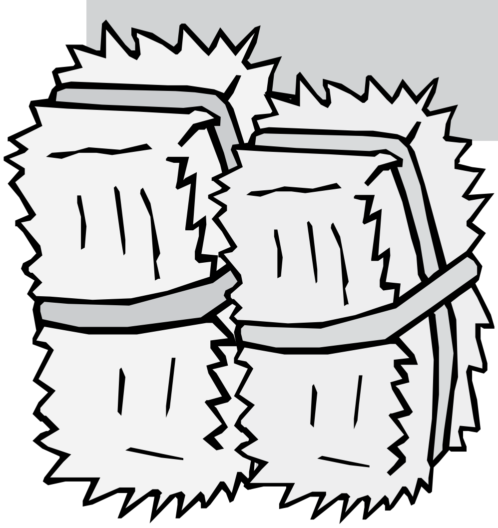
You should use a probe and thermometer to accurately determine the temperature inside a stack of hay. Push or drive the probe into the stack and lower the thermometer to the end of the probe on a lightweight wire. If the probe is horizontal, use a heavier wire to push the thermometer into the probe. After about 15 minutes, retrieve the thermometer and read the temperature. Refer to the following temperature interpretations:

Below 130°F	No problem.
130 to 140°F	No problem yet. Temperature may go up or down. Recheck in a few hours.
150°F	Temperature will most likely continue to climb. Move the hay to circulate and cool the air. Monitor temperature often.
175 to 190°F	Fire is imminent or may be present a short distance from the probe. Call the fire department. Continue probing and monitoring the temperature.
200°F or above	Fire is present at or near the probe. Call the fire department. Inject water to cool hot spots before moving hay. Have a charged hose ready to control fire when moving hay.

Source: Ogburn 1995

Hay Storage Recommendations

There are plenty of theories about how to stack bales in a storage or mow. It is a good idea to stack bales on their sides with the stems of the cut hay running up and down. This allows convection ventilation of warm, moist air up and out of the bale. The greener or moister the hay, the looser it should be packed to allow cooling and curing without danger of mildew formation or combustion. Realize though that loosely packed bales are more prone to tumbling out of their stacked formation. Using pallets, or at least a layer of dry straw, under the bottom row will reduce storage losses from ground moisture. One strong recommendation to reduce fire hazard (with an added benefit of decreasing dust levels in the barn) is to store hay and bedding in a separate building from the horse stable.



Site Plan and Construction Considerations

Fire Codes for Barns

Currently in Pennsylvania, horse barns and agricultural buildings do not have state-mandated fire code requirements. Some states such as New Jersey have enacted fire codes for their agricultural community, and there is some speculation that Pennsylvania is not far from doing the same. Fire codes consider building materials and designate fire prevention techniques based on floor area and use. Fire codes do vary among municipalities, so check the local zoning and building codebook while in the planning stages of construction.

Site Planning for Fire Fighting

Facility design plays an important role not only in fire prevention, but also in fire suppression. Design the facility for accessibility of large rescue vehicles. Be sure that all roads and bridges providing access to the property and between buildings are large enough for emergency vehicles. A 12-foot-wide lane is sufficient and any bridges should support a 40,000-pound fire truck. Bridge requirements will vary depending on the span of the bridge. It may be a good idea to contact your local fire chief to ensure that you meet any requirements for your lane.

An effective tool to prevent the spread of fire between buildings is to place buildings at least 50 to 100 feet away from the stable. The 100-foot distance reduces the chance of fire spreading from building to building through radiation. The 50-foot gap between buildings provides access for fire-fighting equipment. The ground around all buildings should be compacted or sturdy enough to support the weight of heavy equipment, such as a fire truck, during wet conditions. Fire hoses can deliver 250 gallons of water per minute and the ground around the building and truck will get saturated. The fire department will not risk endangering their lives or equipment at a fire scene. Having a surface that can provide access to buildings allows the fire department more options to attack the fire efficiently and safely.

Building Materials

The three rating systems for building materials are flame spread, smoke development, and fire rating. Each rating system compares how well the material in question behaves in a fire compared to a standard. The standard materials are concrete and raw wood, usually red oak. Flame spread ratings indicate how well or poorly a material will prevent flames from traveling along it. Concrete has a flame spread rating of 0 and raw wood, 100. The lower the flame spread rating, the longer it takes for flames to traverse the surface of the material.

A good or low smoke development rating indicates the material produces less smoke as it burns. Less smoke improves visibility, decreases the quantity of noxious gases, and decreases fire progression through smoke particles and gases. Fire ratings tell important characteristics about how long (in minutes) the material contains a fire. The longer the progression of the fire is blocked, the greater chance rescue and fire suppression efforts will have at being successful. Each rating has inherent differences in controlling fires. For example, metal siding on a barn has a good flame spread rating, preventing the spread of flames, but since metal is a good conductor of heat, it has a poor fire rating because it could conduct enough heat to ignite combustible materials behind it.

Use rated fire retardant/resistant products, such as masonry, heavy timber, or fire-retardant treated wood whenever possible. Masonry will not burn, but may be too costly to install, and because masonry construction is so tight, it tends to obstruct air flow. Heavy timber has a greater ratio of volume to surface area. The small surface area compared to the total volume prevents the wood from burning as quickly. In heavy timber construction, fire chars the wood to a depth of approximately 1 inch. The charred surface prevents the flames from accessing the wood in the center of the post, maintaining its structural integrity.

Fire-retardant treated wood decreases flame spread by 75 percent (flame spread rating = 25 for treated wood, 100 for untreated), and if the treatment is properly applied, it will be effective for at least 30 years. Lumber or plywood treated with fire retardant releases noncombustible gas and water vapor below normal ignition points, usually 300–400°C or 572–752°F. When the wood is exposed to flames, a hard-carbon char layer forms on the surface of the wood, insulating it from further damage. Because of this insulation (charring), heavy timber and wood treated with fire retardant retains its structural integrity longer than unprotected steel during a fire.

Treated wood products may withstand the harsh, humid barn environment better than untreated products, but is dependent on the ingredients used. Obtain information on wood strength and recommended fasteners from the manufacturer. The fire-retardant ingredients can be more corrosive to fasteners, especially in a high-humidity setting, characteristic of barns and indoor riding arenas. Be sure that any fire-retardant treated wood is stamped with either the Underwriter's Laboratory or Factory Mutual seal to assure the products meet recent fire-retardant standards of the American Wood Products Association.

Some care must be given to selecting fire-retardant lumber and plywood. The fire-retardant ingredients contain inorganic salts, such as monoammonium and diammonium phosphate, ammonium sulfate, zinc chloridem, sodium tetraborate, boric acid, and guanylurea phosphate, and may not be safe for chewers, cribbers, and foals. Most salts are water soluble and will leach out of the wood if it is frequently washed (such as a wash or foaling stall) or if the barn is continually damp due to poor drainage or inadequate ventilation. In these situations, select fire-retardant wood with low hygroscopicity. Instead of salts, low hygrosopicity materials use impregnated water-insoluble amino resins or polymer flame-retardants grafted directly to the wood fiber. These retardants bond directly with the wood and will not wash out.

Lightning Protection Systems

All barns, regardless of age, should be outfitted with a lightning protection system, commonly referred to as lightning rods. Lightning storms occur in every state, but most prevalently in the central and eastern United States. It is estimated that there are 40 to 80 lightning strikes per square mile each year. Lightning is a stream of pure energy, ½ to ¾ inches thick, surrounded by 4 inches of super-heated air, hot enough to boil and instantaneously evaporate all the sap from a tree at the moment of impact. It looks for a path of least resistance from ground to cloud and has the potential to burn, damage, or kill anything in its path.

A properly installed and grounded lightning protection system is good insurance to minimize the chance of a horse barn catching fire from a lightning strike. The metal air terminal (rod) is the highest part of the building to intercept the lightning bolt, and direct it through a heavy conducting cable, deep into the ground to be harmlessly dissipated. These systems are inexpensive to

Horse Stall on Fire

Protecting a horse stall is not the same as protecting a home. The horse is standing in dry bedding material that is very flammable. Straw reaches a burning temperature of 300°F in 1 to 5 minutes and develops as much heat at the same rate as gasoline. All that is required to start this fire is a spark or match. It takes 2 to 3 minutes for a straw fire to burn an area 10 feet in diameter. Compare this to the size of a common horse box stall that is 10 to 12 square feet. After a fire starts in a stall and spreads to only 4 feet in diameter, most horses are injured. By a 6-foot diameter its lungs are seared. With an 8-foot diameter fire the horse will start to suffocate. By 10 feet, the horse is dead. All of this occurs in 2 to 3 minutes. If the horse is to survive unharmed, he must be removed from the stall within 30 seconds. A quick rescue is key, but fire prevention is more important.

install on existing or newly constructed barns and should be periodically inspected by a qualified professional to ensure that all connections are intact and still work properly. Lightning protection systems should only be installed by a certified installer, not by an amateur. An improperly installed system cannot only fail, but increases the potential of the building being struck by lightning. Certified installers can be found by contacting the Lightning Protection Institute (335 N. Arlingtons Heights, IL 60004, 1-800-488-6864) or the Underwriter's Laboratory (333 Pfingston Road, Northbrook, IL 60062, 1-847-272-8800).

Simple Solutions to Minimize Fire Risk

The Best Way to Prevent Fire Is to Minimize Fuel Sources

- Keep the grass mowed and the weeds down to improve the aesthetics and eliminate a frequently overlooked fuel source (dried plant materials).
- Store hay, bedding, and equipment in a separate section of the barn or, preferably, in its own building.
- Remove less frequently used combustibles from the stable. Store all combustibles properly and be sure to provide appropriate receptacles to dispose of rags soiled with combustibles.
- Keep the barn clean and free of cobwebs, chaff, and dust, which are easily combustible and make excellent fuel sources.
- An ignition source includes the obvious cigarettes and heaters to those not so obvious, such as machinery exhaust systems. Trucks driven into the hay/bedding storage area have been known to ignite materials in contact with the hot exhaust and catalytic converters. Space heaters should only be used according to the manufacturer's guidelines and should not be left unattended.
- Post and enforce a NO SMOKING policy. All smoking should be banned from the barn and immediate premises. If smokers do frequent the barn, provide them with a smoking area away from the barn that is equipped with a receptacle for butts and matches.

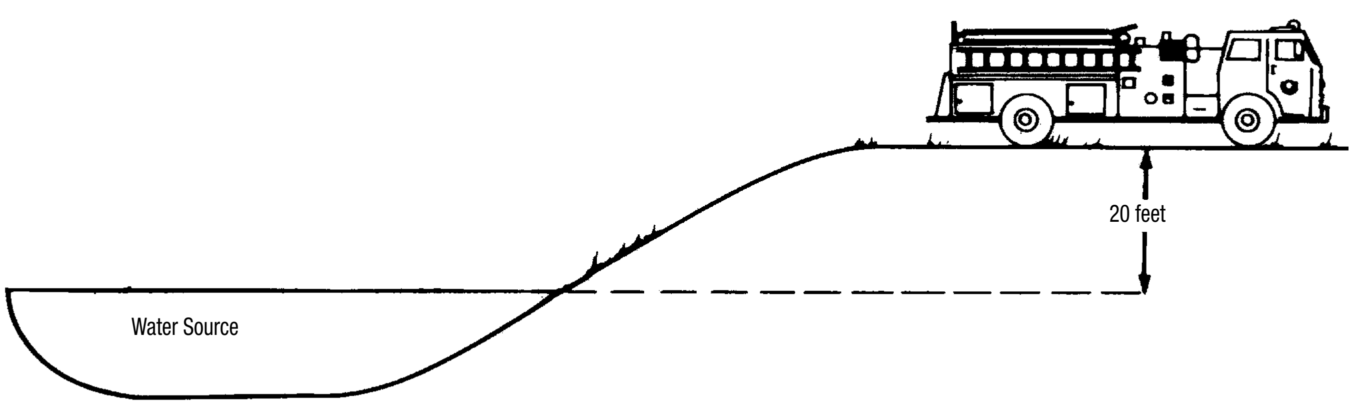
Stable design and management to minimize fire risk

Having water hydrants (more than one) with adequate water volume and pressure located in and around the barn helps in early suppression before the fire company arrives. An alternative is having enough hose available to reach all areas in the barn. In all facilities, hydrants need to be frost-free. If heat tapes are used (but their use is discouraged), be sure to read, understand, and follow all manufacturer warnings and directions. An improperly installed heat tape is a fire hazard.

Locating additional water sources around the barn will save valuable time for firefighters. Water sources include ponds, swimming pools, cisterns, and manure lagoons. The major reason for fire suppression problems in rural communities is the lack of water supply. Any potential wa-

Figure 1. Maximum elevation difference between water source and fire truck.

From *Fire Control in Livestock Buildings,* NRAES-39.



ter source must be no lower than 20 feet below the pump truck elevation (Figure 1). Most large agricultural enterprises develop a pond into the farmstead plan for fire suppression. The farm pond often provides recreational and aesthetic functions as well.

Do not overlook the importance of proper electrical wiring. Old, damaged, or improperly connected wires are a fire hazard, especially in a dusty environment. All wiring should be housed in a conduit and have an UF-B rating. The plastic used in wire insulators is often “sweet” and invites rodents to chew the wires, exposing them to each other. Conduit can be metal, but due to the humidity in barn environments, PVC is preferred.

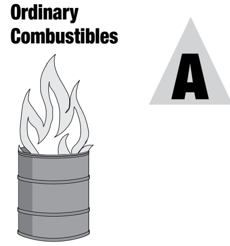
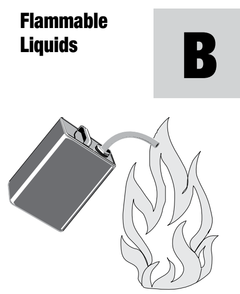
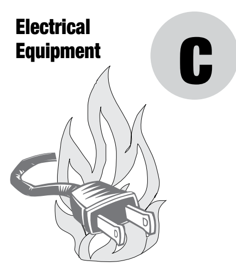
Overloaded circuits or outlets are another recipe for disaster. Inspect and clean electrical panels, wiring, and fixtures frequently. Lighting fixtures and fans should be designed for agricultural use (which is a harsher environment than in residential applications) and have appropriate dust- and moisture-resistant covers. Use products approved by the Underwriter’s Laboratory (UL), keep all electric appliances in good repair, and unplug them when not in use. Electricity to the barn may be turned off at night. Locate master switches near entrances so that light is available for rescue and fire suppression efforts.

Be sure that a charged and mounted fire extinguisher is easily accessible every 50 feet in the barn. The most versatile type of extinguisher is the ABC-type (Figure 2) that extinguishes the broadest range of fire. Extinguishers are not universal. Using a water-type extinguisher can spread fires fueled by flammable liquids, such as gasoline, or become a safety hazard in electrical fires. An ABC type is recommended for locations that may experience different types of fires.

Try to design stalls with two exits for the horse to use in an escape

Figure 2. Fire extinguisher types and codes.

Adapted from Hanford Fire Department Web site information.

Ordinary Combustibles 	**Class A Extinguishers** will put out fires in ordinary combustibles, such as wood and paper. The numerical rating for this class of fire extinguisher refers to the amount of water the fire extinguisher holds and the amount of fire it will extinguish.	Water extinguishers contain water and compressed gas and should only be used on Class A (ordinary combustibles) fires.
Flammable Liquids 	**Class B Extinguishers** should be used on fires involving flammable liquids, such as grease, gasoline, oil, etc. The numerical rating for this class of fire extinguisher states the approximate number of square feet of a flammable liquid fire that a non-expert person can expect to extinguish.	Carbon dioxide (CO_2) extinguishers are most effective on Class B and C (liquids and electrical) fires. Since the gas disperses quickly, these extinguishers are only effective from 3 to 8 feet. The carbon dioxide is stored as a compressed liquid in the extinguisher. As it expands, it cools the surrounding air.
Electrical Equipment 	**Class C Extinguishers** are suitable for use on electrically energized fires. This class of fire extinguishers does not have a numerical rating. The presence of the letter “C” indicates that the extinguishing agent is nonconductive.	Halon* extinguishers contain a gas that interrupts the chemical reaction taking place when fuels burn. These extinguishers are often used to protect valuable electrical equipment since they leave no residue to clean up. Halon extinguishers have a limited range, usually 4 to 6 feet. *carcinogenic and damages ozone
	Many extinguishers available today can be used on different types of fires and will be labeled with more than one designator, e.g., A-B, B-C, or A-B-C.	Dry chemical extinguishers are usually rated for multipurpose use. They contain an extinguishing agent and use a compressed, nonflammable gas as a propellant.
	Class D Extinguishers are designed for use on flammable metals and are often specific for the type of metal in question. There is no picture designator for Class D extinguishers. These extinguishers generally have no rating nor are they given a multipurpose rating for use on other types of fires.	

route. An adequate number of exits are needed so that the fire will not block the only exit(s). Provide easy entrances and exits from all stalls and rooms. Have exits open into an enclosed area so that horses escaping the stable will not have access to nearby roads and traffic or destroy neighbor's property. Be sure to keep all exits clear. A fire door is not an effective exit if it is blocked. Have halters and lead ropes available for each horse.

Swinging stall doors should open out of the stall. Frantic horses will catch a hip on half-open doors. Also, if there is only time for someone to run down the alley opening stall door latches, a horse pushing out on the door can escape on his own. Likewise, sliding doors can be unlatched and pushed open. All latches and fastenings on doors should work quickly to save time.

Post evacuation plans and practice fire drills with all persons and horses in the barn. Post by the phone all emergency numbers, written directions, a list of any chemicals stored on the premises, and any other important information that emergency operators will need. Providing a map of the facility to emergency services will greatly enhance reaction time once emergency medical services (EMS)/fire is on site. This map should indicate where animals are housed, water sources that can be used to help extinguish a fire, and the location and quantity of commonly stored chemicals.

By practicing evacuation drills, both horse and handler can prepare for emergency situations. Teach the horses to walk out with their eyes covered and accustom horses to firefighter turn-out gear, loud noises that simulate sirens, and smoke. If horses are reluctant to walk blindfolded during the drills, chances are that they will be even more reluctant during an emergency situation. Some fire companies are willing to meet with you to train both you and the firefighters. Most firefighters are volunteers who may have little to no horse experience, making handling a frightened horse not only difficult and dangerous, but also potentially lethal.

More Extensive Fire Protection

The best barn fire prevention systems incorporate building design, early warning devices, and fire suppression mechanisms. Building design for fire prevention changes the environment to minimize the spread of heat and flames and provides multiple options for escape. Barn design should increase the time it takes a fire to reach the flash point by modifying ceiling height or room volume, building materials, and building contents.

Compartmentalization

Although not a common practice in Pennsylvania horse barns, one way to slow a fire's spread is to compartmentalize the structure. Compartmentalization divides the stable into "rooms" not longer than 150 feet with fire-resistant barriers such as walls, doors, or fire curtains. This prevents the spread of fire within the building and allows more time for fire suppression. A true firewall must be completely sealed in a fire and should provide at least one hour

Figure 3. Fire wall to prevent or delay the spread of fire.

From *Fire Control in Livestock Buildings,* NRAES-39.

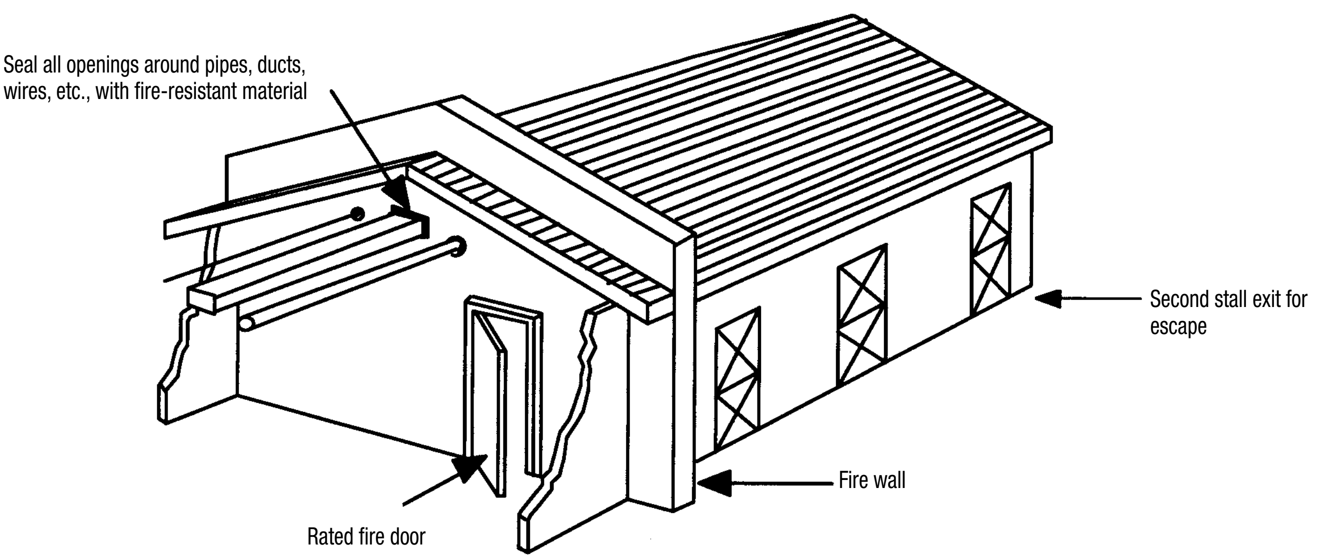
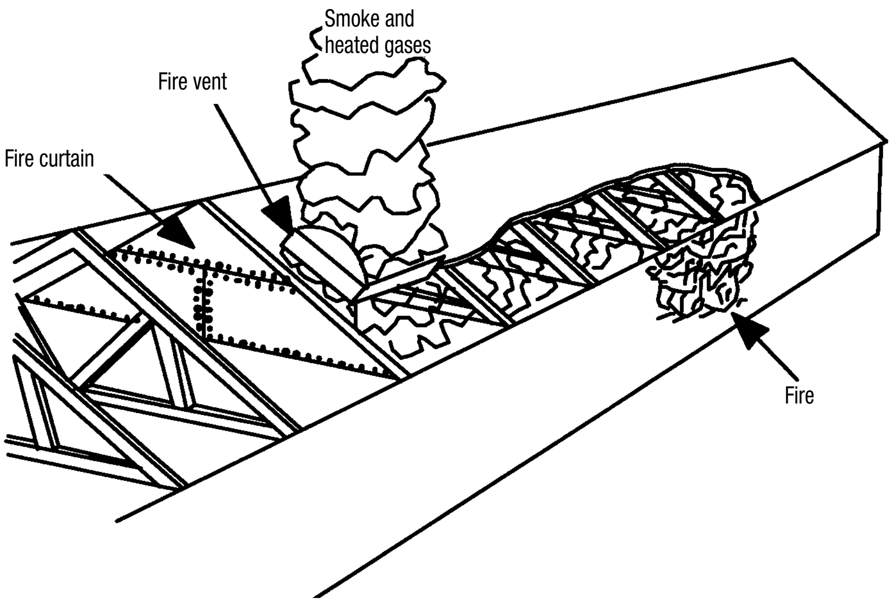


Figure 4. Fire curtain to delay and limit the horizontal spread of heat, smoke, and flame.

From *Fire Control in Livestock Buildings,* NRAES-39.



of fire protection (Figure 3). Any doors in the wall need to be fire-rated and self-closing, and any openings for wiring or pipes need to be sealed. In a stable with a frame-constructed roof, the wall itself needs to extend at least 18 inches above the roof; the higher the wall extends, the longer the fire protection. Fire curtains (Figure 4) or fire barriers are walls that divide up the open space in the roof trusses and prevent the spread of heat and smoke through the attic space. This prevents the truss area from becoming a natural tunnel for heat and flame travel. Building design determines the size of the fire curtain; the taller the fire curtain, the greater the effectiveness.

Compartmentalization is not as simple as just adding a wall. Preventing the exchange and redirection of superheated air and flame is the operating principle of a firewall or curtain. Although if not properly installed, it disrupts the everyday air patterns needed for proper ventilation in the stable. An option more common at horse facilities is to "compartmentalize" by having entirely separate structures rather than dividing up one extra large building. This is one reason why many racetracks have several modest-sized stables rather than one huge stable.

Fire Ventilation

Proper ventilation will also improve survival by removing gases from occupied areas, directing flow of air currents and fire spread, and providing for the release of unburned gases before ignition. Roof vents are an effective way to ventilate a barn during a fire. Recommendations for vent spacing and sizes are set by the National Fire Protection Association, based on building material types and area to be vented. The most important factor to determine the space needed between vents is the rate at which burning material gives off heat. Horse barn fires burn with moderate-to-high heat production. Stables should have 1 square foot of ceiling vent space for every 100 square feet of floor area. Buildings with hay storage need 1 square foot for every 30 to 50 square feet of floor area. Options include a continuous slot opening along the ridge; roof vent monitors with louvers or thin glass that are opened by the super-heated air; and unit vents that are designed to melt, collapse, or spring open at predetermined temperatures. Each of these vents increases gas removal during the fire. Vents on heat-triggered fuses (usually set to open at 212°F) may not open unless a hot, free-burning fire produces smoke temperatures high enough to activate fuses. This may mean that the fire has had time to progress, depending on its origin. Do not assume that just because vents are installed, the environment within a burning barn is livable. A smoldering fire can produce enough toxic smoke to be an immediate threat to human and animal life.

Fire Detection Devices and Principles

Early warning devices can be an effective tool in fire detection but few are suitable for barn use. In some situations, the main goal is to save the animals housed in the barn, but in other situations, minimizing property damage is the priority. Many early detection and fire suppression systems are available, but most were developed for residential use. This severely limits their practicality in horse or livestock facilities since they tend to be dustier, more humid, and colder than residential environments. It is best to seek advice and recommendations from fire engineers or fire protection professionals familiar with the unique needs and situations found in horse facilities. If you have trouble locating fire protection professionals, contact your fire department and ask for referrals.

Early warning devices were developed to mimic human senses. There are three basic types of fire detection devices: smoke, thermal (heat), and flame detectors. Smoke detectors mimic the human sense of smell. An ionization detector charges the air within the detector so that it will carry an electric current and any resistance to the electrical current will set off an alarm. Smoke particles and dust will interrupt the air's ability to conduct electrical current. An ionization detector is more responsive to a flaming fire than a smoldering one. For earlier smoke detection a photoelectric smoke detector is recommended. Within a chamber in the smoke detector, is a light-sensitive photocell. Smoke particles and dust will act like miniature mirrors, scattering a light beam and directing it towards the photocell. Once the amount of light detected by the photocell reaches a predetermined point, the alarm is activated.

Smoke detectors are the best line of defense for early warning of fires. They identify the fire while it is in the smoldering or early flame stages. Smoke detectors are not as reliable in the dusty and humid environment of horse barns. Airborne dust and dander or humidity may trigger false alarms. In more controlled environments, such as a lounge or office, a smoke detector is better suited.

Thermal detectors, developed in the mid-1800s, are the oldest type of automatic detection device. They are inexpensive to install and easy to maintain. The most common thermal detectors are fixed temperature devices, set to operate when temperatures reach a predetermined level, usually 135 to 165°F. Another class of thermal detectors, called rate-of-rise detectors, activates an alarm when the temperature climbs at an abnormally fast rate. Both fixed temperature and rate-of-rise detectors are spot detectors and activate sooner with a closer proximity to the heat source.

A third type of thermal detector, the fixed temperature line detector, does not require the sensor to be as close to the heat source for activation. Two wires are run between detectors. Alarms are activated when the insulators, designed to degrade at a specific temperature, are damaged. The benefit of this fixed temperature line sensor is that floor area coverage can be increased at a lower cost. Thermal detectors are highly reliable and are not as affected by a dusty, moist environment. However, their adequacy in a horse barn is debatable since they require the fire to be in the later stages of progression before the sensor recognizes and signals the alarm. The longer a fire has to develop, the greater damage it can cause and the more difficult it is to control, especially in a barn. This is why they are usually not permitted as the sole detection device in life safety applications, such as in residential use.

Figure 5. Keep all detectors free of cobwebs and dust.

From *Fire Control in Livestock Buildings,* NRAES-39.

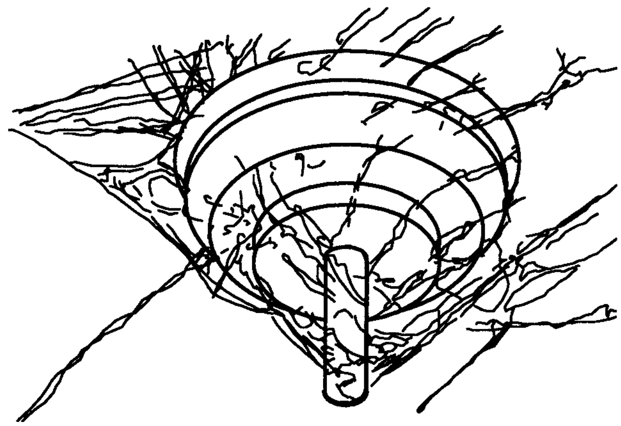
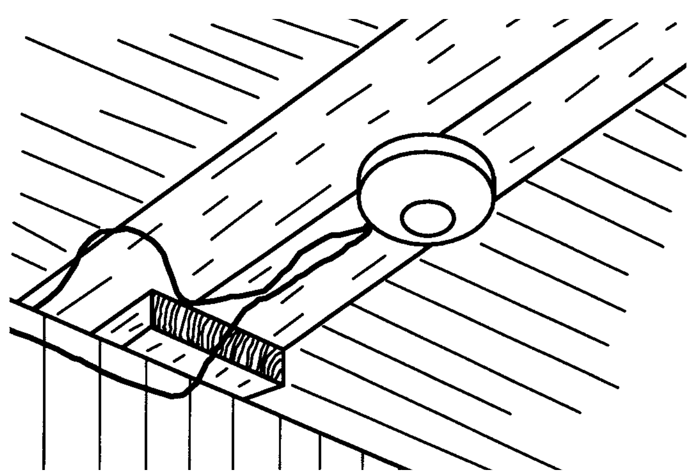


Figure 6. Many fire detection devices, such as this smoke detector, were developed for residential use which severely limits their application to dusty, humid barn environments.

From *Fire Control in Livestock Buildings.* NRAES-39.



The most reliable and expensive early warning detection device is the flame detector. These sensors imitate human sight and are most commonly used in aircraft maintenance facilities, refineries, and mines. As with other spot detectors, flame detectors must be "looking" directly at the fire source. Flames are classified by short wavelengths of electromagnetic radiation flickering in the range of 5 to 30 cycles per second. When the device senses these conditions, it is preset to monitor the source for a few seconds, before sounding the alarm. By recognizing the flame's wavelength, cycle, and consistency, flame detectors differentiate between hot objects and actual fires, minimizing false alarms. The greater the distance the flame is from the sensor, the larger it must be before the sensor will respond to it. They are highly reliable early detection devices especially for hot burning fires that are not likely to give off smoke, such as alcohol or methane fires.

Early warning systems can add valuable time to rescue efforts, if someone is available to hear them. One way to ensure that someone is alerted when a fire is detected is through a telephone dialer. A telephone dialer provides 24-hour alarm monitoring. The dialer can be connected to a professional monitoring service, family, neighbors, or directly to the fire department. It may be best to alert someone near the premises first, to prevent calling the fire department for any false alarms. However, best judgement should prevail, and if the nearest neighbor is too far away, contacting the 911 operator may be a better alternative. A phone dialer will need its own line, to ensure the availability of a phone connection after a fire has been detected.

Automatic Fire Suppression

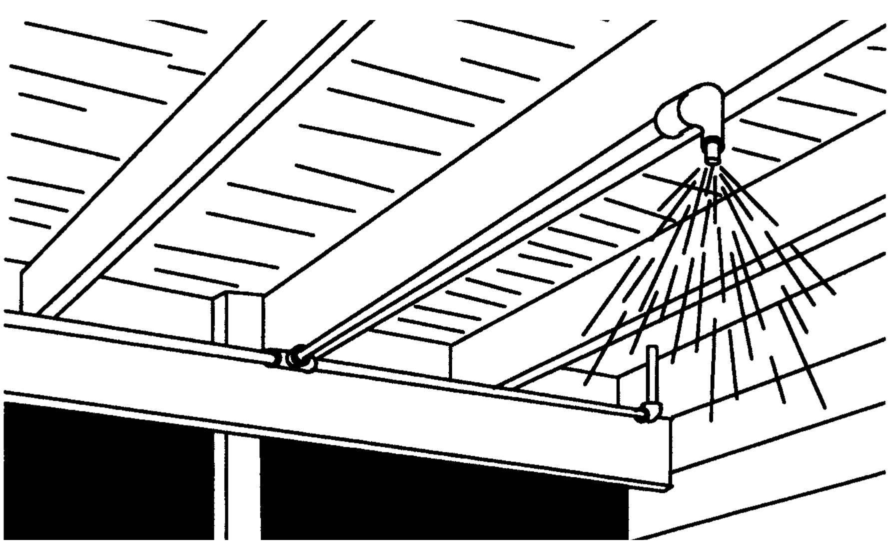
Sprinkler systems are an effective tool for controlling fires but are not common in rural horse barns. Most sprinkler systems open to apply water to a fire when a sensing element in the individual sprinkler head comes in contact with intense heat. Only the sprinkler heads that come in contact with the fire's heat react, minimizing the water needed to extinguish the fire. A sprinkler system usually suppresses a fire with as few as two sprinkler heads and is very effective at controlling fires before they get out of hand. However, for sprinkler systems to be effective, an adequate water supply needs to be available at all times to provide enough gallons and sufficient pressure to extinguish the fire. It is often difficult for rural horse farms to meet these criteria. On average, one sprinkler head will deliver 25 gallons of water per minute to extinguish the blaze. As more sprinklers are activated, more water must be available to maintain pressure in the line (47 gallons and 72 gallons per minute for activation of the second and third sprinklers, respectively.) If water availability is a problem, a tank can be installed (Figure 5). This is an extremely expensive addition that will need regular service checks and maintenance.

If the facility's water supply is sufficient, several options are available for sprinkler systems. A sprinkler system that holds water all the time is called a wet-pipe system. These are the most inexpensive systems to install and require the least amount of maintenance. However, in climates where the barn temperature is too low to prevent freezing, the wet-pipe system will not work.

In freezing environments, a dry-pipe system is employed. The supply lines are pressurized with air or nitrogen gas to hold a valve closed, preventing water from entering the system. In a fire, the sprinklers are activated, releasing the pressure and opening the valve. If the pressure is released through damage to the supply line, the valve is also released. This poses problems if the valve release is not found and temperatures are low enough for freezing to occur. Dry-pipe systems are more limited in design. The reliance on pressure to close a valve creates strict requirements on the overall size and locations of the sprinkler heads and supply lines. The increased system complexity requires more components, has more opportunity for failure, and increases the costs of installation and maintenance.

Figure 7. Sprinkler installed in barn.

From *Fire Control in Livestock Buildings,* NRAES-39.



A preaction system was designed to eliminate the danger of accidental valve release on the dry-pipe system. A preaction system uses an electronically operated valve to prevent water from prematurely entering the pipes. In order for the valves to be opened, an independent flame, heat, or smoke detection device must identify a fire or potential fire. Once a fire is detected, the valve is released and the water is available to the sprinkler heads. The sprinklers open when triggered by heat, not by the valve detection device. As with an increasingly complex system, installation and maintenance costs increase along with the potential for malfunction.

One promising technology for areas with limited water supplies is the water mist. This system was originally designed for controlling severe fires on ships and oil-drilling platforms, where excessive water use could make the vessel capsize. Currently, these systems are standard on marine vessels, and have a proven record of extinguishing maritime fires. Their applications in buildings have been recognized and used in Europe. Water mist systems are highly pressurized, ranging from 100 to 1,000 psi and produce finer droplets 50 to 200 microns in diameter (sprinklers deliver 600 to 1,000 micron droplets). These smaller droplets are exceptionally efficient at cooling and fire control with 10 to 25 percent less water than a sprinkler system. Due to its limited availability, this technology is significantly more expensive than sprinkler systems. Currently, insurance companies do not recognize water mist systems as a fire suppression system and will not give rate incentives for them. Recognition of and advancements in this technology should bring it closer to affordable horse farm applications.

What to Do if You Have a Fire

#1. Remain Calm

The most important thing to do is remain calm. The situation may be perilous, but panic is only going to make it worse. Panic can create situations that endanger lives. Take a deep breath, stop, and plan.

#2. Survey the Scene

This is the most important and most often forgotten step. **IF THE AREA IS NOT SAFE, GET OUT!** Botched acts of heroism will only jeopardize lives and the structure. Look and see what the fire is near. A smoldering pile of hay is not nearly as deadly as one smoldering near bags of fertilizer. Take a quick inventory of available resources. Are there other people present? Use their skills in the most efficient manner possible. Remember, because of their behavior patterns, horses are the most difficult domestic livestock species to evacuate from a burning barn. Always send the most qualified person to do the task. Persons who are not qualified to do the task are more of a liability than assistance. A person who is unfamiliar with operating a fire extinguisher may spread the fire. Someone unfamiliar with the behavior of a panicked horse puts others, themselves, and the horse in greater danger. If the area is unsafe to enter, don't put yourself or anyone else at risk. Be alert for potential hidden dangers. Firefighters cannot concentrate on saving the horses until they have rescued the people.

Investigating a smoldering haystack or mow is especially dangerous. If smoke is seen or smelled in hay, do not attempt to move it or walk on it. Disturbing the hay may expose the smoldering sections to oxygen, causing it to flash quickly. Smoldering cavities are prone to collapse. Burned-out cavities may collapse under weight and trap a person who was attempting to stand or walk on the bale.

Surveying the fire scene only takes a fraction of a second, but is the single most important step to ensure everyone's safety.

#3. Call 911 or the Fire Department

Regardless of the size of the fire or potential fire, call the fire department. Even if the fire was contained without professional help, contact the fire department immediately and have the area inspected to ensure the fire has been completely extinguished. Firefighters are trained, certified, and experienced in fire control. It is better to catch a blaze in the earliest stages than have it get out of hand.

Be sure that whoever is calling the emergency dispatch operator is capable of giving clear, concise directions and other valuable information. Also include the county, state, and municipality if using a cell phone. The nature of the fire (barn fire, hay storage shed, etc.), how far the fire has gone (still smoldering, flames erupted, structure totally engulfed), and whether any people/animals are trapped in the structure are invaluable pieces of information for dispatching emergency crews.

#4. Evacuation

If time permits, get the horses out and into a safe pasture. Once the flames have erupted, the fire will spread quickly and pose an immediate danger to life. Put horses in a secure, fenced area, as far away from the commotion as possible. During a fire, many situations are present that can distress even the most “bomb-proof” horse. Loose horses running amid the lights, sirens, and moving trucks can be hit, injure firefighters, or even run back into the burning barn. Using a pasture right next to the barn will endanger the horse(s) and inhibit fire-fighting measures.

Summary

Although a serious threat because its rapid spread and destructiveness, horse barn fires are largely preventable. Take steps to reduce the chances of fire in your facility. Fortunately, much of fire protection involves simple, common-sense prevention measures.

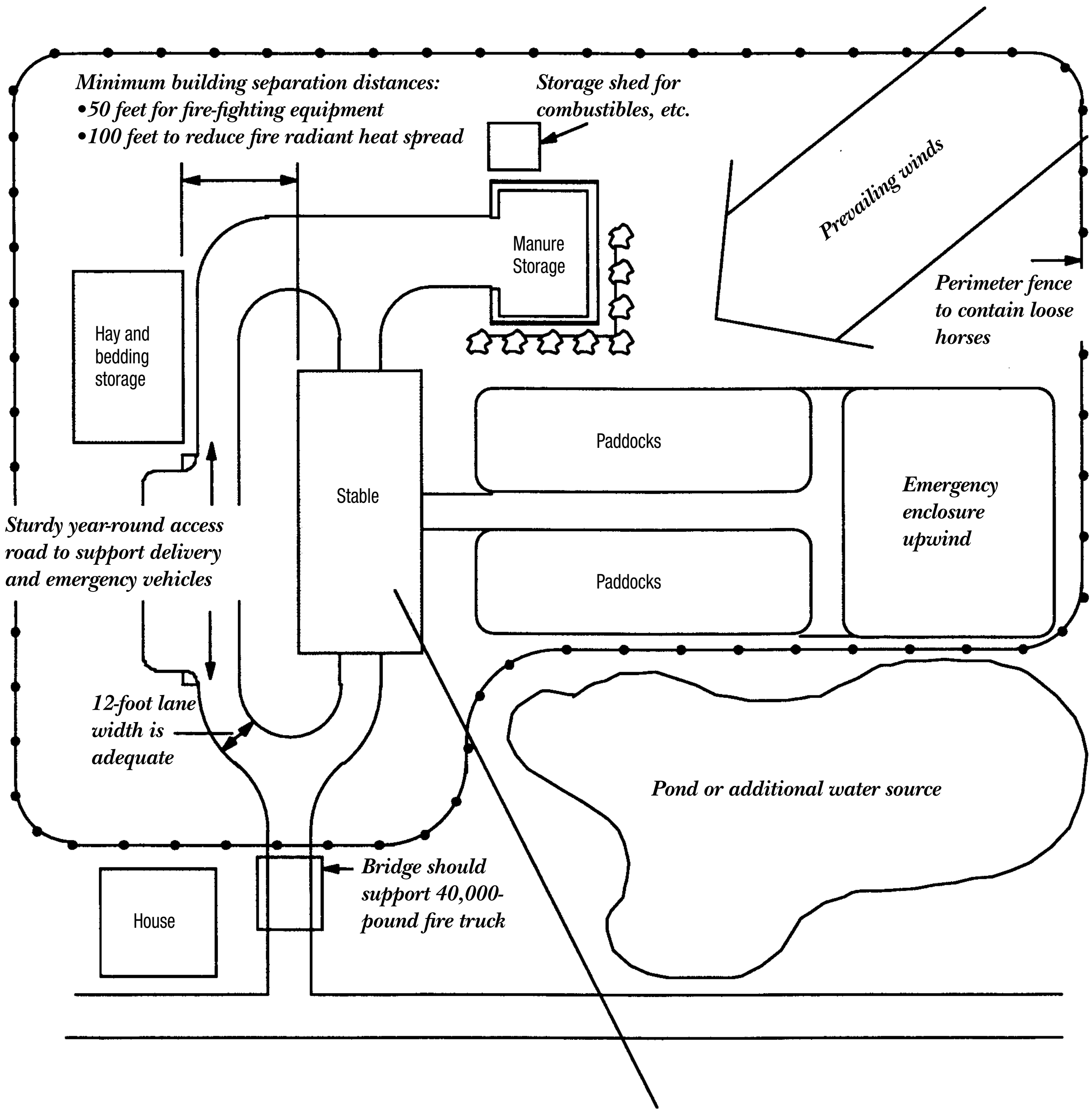
- Fire requires a fuel source, an ignition source, and oxygen and goes through four growth stages: incipient, smoldering, flame, and heat production.
- Baled hay can be its own fuel and ignition source if it is baled too wet. Wet hay should be monitored for heat build-up, caused by microbial respiration.
- Store hay and bedding in a separate building from the horse stable.
- Minimize fuel and ignition sources in and around the barn. Be sure to store and dispose of combustible materials properly.
- Keeping the barn neat and clean has aesthetic appeal, will minimize the risk of fire, and increase the chances of escape during a fire.
- Post and enforce a No Smoking policy.
- Be sure that the facility is accessible to emergency vehicles and that the ground around the buildings is sturdy enough to support them.
- An effective tool for preventing fire spread is to separate the buildings.
- The three fire control rating systems for building materials are flame spread, smoke development, and fire rating.
- Fire retardant/resistant products include masonry, heavy timber, and fire-retardant, treated wood.
- All barns should be outfitted with a lightening protection system and inspected regularly. Only certified professionals should install and inspect the lightning protection system.
- Having multiple water hydrants around the barn will give more options for early fire suppression.
- Know where additional water sources (e.g., ponds) can be located.
- Have at least one charged and mounted ABC-type fire extinguisher every 50 feet.
- Be sure wiring and all electrical equipment is rated for agricultural use, is in working condition, is free of dust and cobwebs, and is housed in PVC conduit. Wires with UF-B ratings are preferable.
- Design stalls with two exits that open into a secure, enclosed area and be sure that any swinging doors do not obstruct pathways.
- Have halters and lead ropes easily accessible on stall doors.
- Post written emergency information at each phone. This information should include written directions to the facility and a list of commonly kept combustibles.
- Post and practice evacuation routes.
- A more elaborate barn fire protection system may incorporate building design, early warning devices, and fire suppression mechanisms.

IN CASE OF FIRE

1. **Remain calm**
2. **Survey the scene**
3. **Call 911 or Fire Department**
4. **Evacuation**

- Many early detection and fire suppression systems are available, but most were developed for residential use. This severely limits their practicality in horse facilities. Barn environments tend to be dustier, more humid, and colder than residential environments, which decrease the life of the detector and may cause the sensors to indicate false alarms.
- Use sprinkler systems that have adequate water pressure. These systems can be expensive to install and maintain in freezing climates, but do have a proven history of containing fires and saving lives.
- Seek advice and recommendations from fire engineers or fire protection professionals familiar with the unique needs and situations found in horse facilities.
- Check local zoning and building codebooks for fire regulations in your area.
- If you do have a barn fire, don’t put yourself or someone else in danger. Think out your actions first.

Site Features for Fire Prevention and Fighting



Stable features:

- No smoking policy
- Lightning protection
- Agricultural electrical wiring
- Written emergency information at each phone
- Fire extinguishers
- Water hydrants
- Stalls with two exits

Additional Resources

Accident Prevention Manual for Industrial Operations. National Safety Council. 1988. R. R. Donnelley & Sons, Chicago, IL.

Ogburn, C. B. Sept. 1995. *Guarding Against Hay Fires,* ANR-964. Alabama Cooperative Extension Service, Agricultural Engineering, Auburn University, Auburn, AL. **www.aces.edu/department/extcomm/publications/anr/anr-964/anr-964.html**

Agricultural Safety and Health Best Management Practices. 2000. Penn State Department of Agricultural and Biological Engineering (contact information below).

Fire Control in Livestock Buildings, NRAES-39. Arble, W. C. and D. J. Murphy. 1989. Northeast Regional Agricultural Engineering Service (NRAES), Ithaca, NY.

Extinguishing Fires in Silos and Hay Mows. NRAES-18. 2000. D. J. Murphy and W. C. Arble. Natural Resource, Agriculture, and Engineering Service (NRAES), Ithaca, NY.

Fire safety information, including extensive extinguisher specifications, is available at the Hanford Fire Department Website: **www.hanford.gov/fire/index.htm**

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