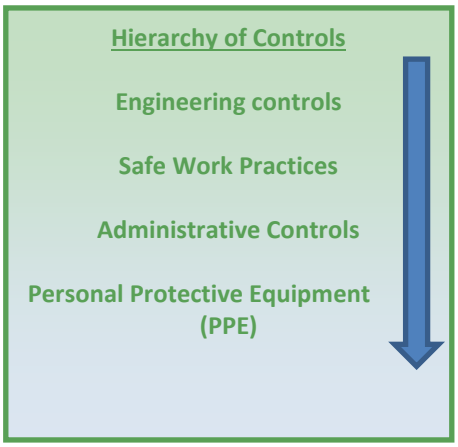
Section IV: Safety Measures

This section reviews some safety measures that could be implemented to prevent workers exposure to the hazards that were discussed in Section III (IAFC, 2008). Often-times facilities have many different types of controls available to them and will typically adopt those best suited for specific applications. The basic concept behind engineering controls is that, to the extent feasible, the work environment and the job itself should be designed to eliminate hazards or reduce workers exposure to an acceptable measure. Where engineering controls are not feasible, or do not completely eliminate or reduce workers exposure to permissible levels, other safety measures must be implemented; these include (in order of precedence) safe work practices, administrative controls (e.g., rotation of workers), and PPE (OSHA Hazard Prevention and Controls).



PSM requirements must be implemented when a process involves a chemical at or above the specified threshold quantities, listed in Appendix A of the PSM standard and/or involves 10,000 pounds or more of a flammable gas or liquid if the exemption discussed in Section I does not apply.

A. Engineering Controls for Flammable Liquids

Several different engineering controls are available to prevent hazards related to flammable liquids such as ethanol and gasoline (III.A). Generally speaking, there are two types of these controls: (1) those that prevent or control the release of flammable vapors, and (2) those that eliminate ignition sources (29 CFR 1910.106(h)(7)(i)(a)). PSM covered facilities have specific safety requirements that employers must implement (OSHA, 2000; 29 CFR 1910.119). The following are examples of the types of controls that might be seen at these facilities:

- *Control of ethanol releases (e.g., in production areas and ethanol loading areas).* Equipment must be designed and arranged to prevent the unintentional escape of liquids and vapors and to minimize the quantity escaping in the event of accidental release (29 CFR 1910.106(h)(4)(iv)(a)). There are several ways to minimize the amount of ethanol vapors in the open workspace. This includes process equipment that is designed to handle process upsets, for example, the incorporation of safety relief valves that avoid equipment failure by venting excess ethanol streams directly to safe areas. Drains in certain production areas can be designed to quickly move spilled chemicals from surfaces into enclosed tanks. Similarly, tanks and railcars can be equipped with vapor recovery systems that collect the ethanol vapors that would otherwise be released when tanks are filled with liquids. Overfill protection devices can also minimize spills from tanks and other vessels. Dikes may be used to contain any spilled ethanol with drainage to a safe area (e.g., where sources of ignition are absent or prohibited). Other safety measures to prevent fires and/or explosions in these areas include proper bonding and grounding (discussed below) and the installation of Hazard Class I electrical equipment and wiring.
- *Controls for electrical wiring and equipment.* One of the principal engineering controls for preventing electrical equipment and wiring used in ethanol production areas from constituting a source of ignition is to ensure that they are rated for environments containing flammable vapors (29 CFR 1910.307(a)(1); 29 CFR 1926.407). Specifically, processing and handling areas involving ethanol vapors are referred to as Hazard Class I locations according to the National Electrical Code (NEC, NFPA 70). A Hazard Class I location is an area where the existence of flammable gases or vapors in air pose a hazard because they could ignite or explode. Each area within the facility must

be rated appropriately, for example, Class I Division I or Class I Division II (NFPA 497; NFPA 70). However, there may be locations within the facility that may not qualify to be classified as a hazardous location, for example, office areas, where the hazards of a classified location do not exist.

Electrical equipment and wiring used in hazardous classified locations must be of a type and design that the employer demonstrates will provide protection from the hazards arising from the flammable vapors involved (29 CFR 1910.307(c)(3)), for example, electrical design specified by and installed in accordance with the NEC. These include explosion proof equipment and intrinsically safe electrical equipment (Figure IV. 1) that is rated for the specific hazardous classified location. Equipment must be identified not only for the class of the location but also for the explosive or ignitable properties of the specific vapor that will be present (NFPA 70; 29 CFR 1910.307(a)(1)). The electrical equipment's rating is based on the performance of the equipment when tested in a specific flammable atmosphere by a nationally recognized testing laboratory (e.g., Underwriters Laboratories, Canadian Standards Association, etc.).

- *Controls for static electricity.* Another source of ignition is static electricity. Ignition by static electricity can be prevented in the design and operation of equipment, and by using proper bonding and grounding mechanisms (described below).

Figure IV. 1 A Telephone Rated for Class I Hazardous Location

- *Control of Flammability Hazards in Storage Tanks Headspace.* Controls include:
    - *Bonding and Grounding (*Figure IV. 2). Bonding is the process of electrically connecting conductive objects, like tanker-trailers, to transfer pumps to equalize their individual electrical potentials and prevent sparking. Grounding (earthing) means connecting a

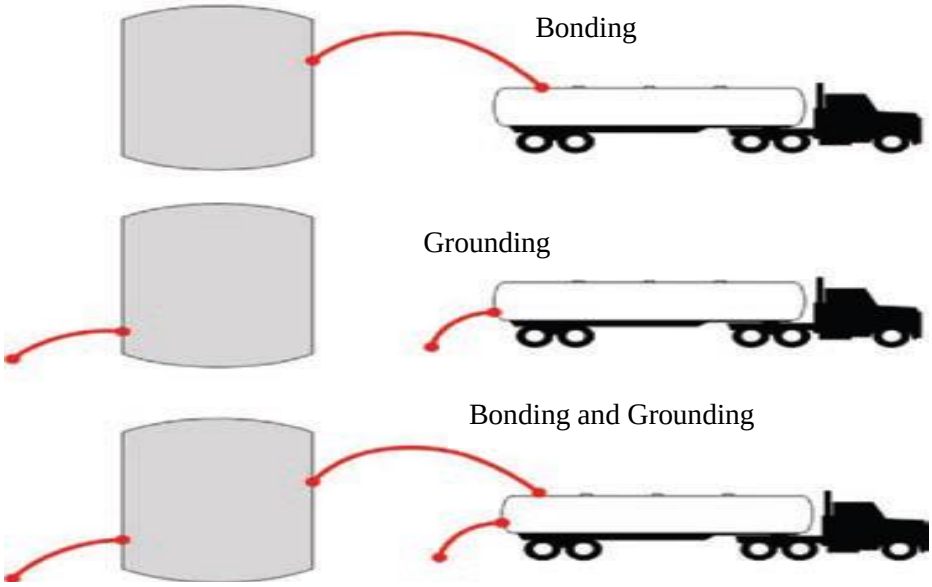
conductive object to the earth to dissipate electricity (e.g., accumulated static, lightning strikes, and equipment faults) into the ground, away from workers, equipment, and ignitable mixtures. Bonding and grounding mechanisms must be implemented simultaneously to safely discharge static charges.

- *Inerting the headspace*. Using an inert gas such as nitrogen, if done correctly, is effective in reducing the potential for an ignitable incident (explosion) as it renders tank head spaces incapable of supporting ignition from a static spark. However, because this practice can produce oxygen-deficient environments inside tanks, safety procedures must be implemented when opening tanks for routine inspections and maintenance.

- *Cross venting to keep oxygen out of the headspace*.

- *Installing flame arrestors on atmospheric vents.*

Figure IV. 2 Illustration of bonding and grounding



Courtesy USCSB

- *Controls for Heated Storage Tanks*. Employers should only use tanks designed to comply with the required safety standards (Myers, 1997). Essential safeguards include: electrical equipment designed for use in processes involving flammable liquids (Hazard Class I); proper bonding and grounding to safely discharge static electricity; automatic temperature controls to prevent overheating; alarms and automatic shutdown systems that would detect hazardous conditions, such as high temperatures and safely turn off the system; ventilation systems in flammable storage and processing areas in compliance with the requirements of 29 CFR 1910.106 and designed in accordance with accepted engineering practices such as the Flammable and Combustible Liquids Code (NFPA 30) and the Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids (NFPA 91).

- *Explosion relief venting*. Areas where category 1 or unstable liquids are processed (in processing plants) must have explosion relief venting through one or more of the following methods: open air

construction, lightweight walls and roof, light weight wall panels and roof hatches, and windows of explosion venting type (29 CFR 1910.106(h)(3)(iv)). Equipment shall be designed and arranged to prevent the unintentional escape of liquids and vapors and to minimize the quantity escaping in the event of accidental release (1910.106(h)(4)(iv)(a)). Where the vapor space of equipment is usually within the flammable range, the probability of explosion damage to the equipment can be limited by inerting, by providing an explosion suppression system, or by designing the equipment to contain the peak explosion pressure which may be modified by explosion relief. Where the special hazards of operation, sources of ignition, or exposures indicate a need, consideration must be given to providing protection by one or more of the above means (1910.106(h)(4)(iv)(b)).

- *Design of piping, valves and fittings in processing plants*. The design (including selection of materials) fabrication, assembly, testing, and inspection of piping systems containing flammable liquids must be suitable for the expected working pressures and structural stresses. Conformity with the applicable provisions of Pressure Piping, American National Standards Institute B31 series (American Society of Mechanical Engineers, ASME B31 series) and the provisions of 29 CFR 1910.106(c)(1), is considered prima facie evidence of compliance (29 CFR 1910.106(c)(1)(i)).

- *Mechanical Integrity*. It is important to ensure that critical process equipment is designed and installed correctly and operates properly. Employers must establish and implement written procedures to maintain the ongoing integrity of process equipment. Workers involved in maintaining process equipment must be trained in the overview of the process, its hazards, and the procedures applicable to their specific tasks. The requirements for maintaining the mechanical integrity of equipment in PSM covered facilities apply to the following (29 CFR 1910.119(j)):
    - Pressure vessels and storage tanks;
    - Piping systems (including piping components such as valves);
    - Relief and vent systems and devices;
    - Emergency shutdown systems;
    - Controls (including monitoring devices and sensors, alarms, and interlocks); and,
    - Pumps.

  In constructing new plants and equipment, the employer must ensure that the fabricated equipment is suitable for the process that it will be used in (29 CFR 1910.119(j)(6)(i)). Appropriate checks and inspections must be performed to ensure that equipment is installed properly and is consistent with design specifications and the manufacturer's instructions (29 CFR 1910.119(j)(6)(ii)).

- *Other engineering controls.* Ethanol manufacturing facilities are typically equipped with many additional engineering controls designed to prevent or mitigate hazards from flammable chemicals. At some facilities, continuous ethanol vapor monitoring devices are installed in key production areas. The devices are equipped with multiple alarm levels designed to trigger increasingly serious actions as detected ethanol vapor concentrations increase (e.g., sounding audible alerts in process control rooms, shutting down process flows, initiating precautionary fire suppression). Similarly, automatic fire detection and suppression systems are usually installed at critical points within production areas, such as tank storage areas and ethanol load-out areas. Suppression systems typically can be activated through both automatic and manual means.

B. Safe Work Practices When Working with Flammable Liquids

The HCS (29 CFR 1910.1200) specifies that employers with hazardous chemicals in their workplaces must develop, implement, and maintain at each workplace, a written hazard communication program (29 CFR 1910.1200(e)) which at least describes how the criteria specified in paragraphs (f), (g), and (h) of the

standard for labels and other forms of warning, safety data sheets, employee information, and training will be met (29 CFR 1910.1200(e)(1)).

There are also specific requirements for safe work practices in facilities covered by the PSM standard (29 CFR 1910.119). The employer must develop and implement safe work practices to provide for the control of hazards during work activities such as lockout/tagout; confined space entry; opening of process equipment or piping; and, control of the entrance into the facility by maintenance, contractor, laboratory, or other support personnel. These safe work practices must apply both to employees and contract workers (29 CFR 1910.119(f)(4)).

Examples of safe work practices at ethanol processing facilities include:

- *Signage and barriers*. All Class I areas where ethanol vapors may be present should be carefully delineated. Signage can be used to inform workers when they are entering Class I areas. In some cases, facilities may choose to erect fences and other barriers to ensure that only authorized personnel work in the designated Class I locations.

- *Prohibit smoking*. Smoking must not be permitted as a precaution to prevent fires/explosions (29 CFR 1910.106(h)(7)(i)(a)) in or near areas where flammable liquids are stored or processed.

- *Hot work programs.* Employers must implement rigorous hot work programs to ensure that workers and contractors follow important safety procedures before performing any cutting, welding, and other related activity near areas that may contain flammable liquids (29 CFR 1910.106(h)(7)(ii)(*b*).

  A permit must be issued for hot work operations conducted on or near a PSM covered process. The permit must document that the fire prevention and protection requirements in OSHA standards have been implemented prior to beginning the hot work operations; it must indicate the date(s) authorized for hot work; and identify the object on which hot work is to be performed. The permit must be kept on file until completion of the hot work (29 CFR 1910.119(k); 29 CR 1910.252(a)).

  Typical elements of an effective hot work program include: definitions of hot work and hazardous locations; inspections of affected work areas; multiple approvals needed before commencing work; and requirements that workers performing hot work operate continuous ethanol vapor detectors to ensure that no flammable vapors are present. These programs should also specify personal protective equipment (PPE) requirements, which may require workers performing hot work to wear flame-retardant clothing.

- *Management of Change*. A procedure should be established in the workplace to ensure that changes to any operation or process are safely implemented. Employers responsible for facilities that are covered by the PSM standard must establish and implement written procedures to manage changes (except for "replacements in kind") to process chemicals, technology, equipment, and procedures; and, changes to facilities that affect a process that is covered by the PSM standard (29 CFR 1910.119(l)(1)). The procedures must include the technical basis for the change; impact of the change on safety and health; modifications to operating procedures; necessary time period for the change; and, authorization requirements for the proposed change (29 CFR 1910.119(l)(2)). Operating procedures and process safety information must be updated as applicable (29 CFR 1910.119(l)(4) & (5)). Affected workers, including contractors, must be informed of the change and receive appropriate training before starting up the process or affected part of the process (29 CFR 1910.119(l)(3)).

- *Training*. The HCS (29 CFR 1910.1200) requires employers to provide workers with effective information and training on hazardous chemicals in their work area (29 CFR 1910.1200 (h); 29 CFR 1926.59). The specific training requirements for facilities that are covered by the PSM standard are:

  - *Initial training.* PSM requires that each worker presently involved in operating a process or a newly assigned process must be trained in an overview of the process and in its operating procedures. The training must include emphasis on the specific safety and health hazards of the process, emergency operations including shutdown, and other safe work practices that apply to the worker's job tasks (29 CFR 1910.119(g)(1)).

  - *Refresher training.* PSM also specifies that refresher training must be provided at least every three years or more often if necessary to each worker involved in operating a process to ensure that the worker understands and adheres to the current operating procedures of the process. The employer, in consultation with the workers involved in operating the process, must determine the appropriate frequency of refresher training (29 CFR 1910.119(g)(2)).

  - *Training documentation.* The employer must determine whether each worker operating a process has received and understood the training required by PSM. A record must be kept containing the identity of the worker, the date of the training, and how the employer verified that the worker understood the training (29 CFR 1910.119(g)(3)).

- *Safe Operating procedures.* Maintenance and operating practices in flammable liquid processing plants must be in accordance with established procedures which will tend to control leakage and prevent the accidental escape of flammable liquids (29 CFR 1910.106(h)(8)(i)). Employers covered by the PSM standard must develop and implement written operating procedures consistent with the process safety information. The operating procedures must provide clear instructions for safely conducting activities involved in each covered process (29 CFR 1910.119(f)(1)).

  Operating procedures must be readily accessible to workers who work in or maintain a process (29 CFR 1910.119(f)(2)). This will form a foundation for needed training for workers and ensure that a ready and up-to-date reference is always available. The operating procedures must be reviewed as often as necessary to ensure that they reflect current operating practices, including changes in process chemicals, technology, equipment, and facilities. To guard against outdated or inaccurate operating procedures, the employer must certify annually that these operating procedures are current and accurate (29 CFR 1910.119(f)(3)).

  The procedures must address at least the following elements:

  - *Steps for each operating phase:*
    Initial startup;
    Normal operations;
    Temporary operations;
    Emergency shutdown, including the conditions under which emergency shutdown is required, and the assignment of shutdown responsibility to qualified operators to ensure that emergency shutdown is executed in a safe and timely manner;
    Emergency operations;
    Normal shutdown; and,
    Startup following a turnaround, or after an emergency shutdown (29 CFR 1910.119(f)(1)(i)).

- *Operating limits:*
  Consequences of deviation, and steps required to correct or avoid deviation (29 CFR 1910.119(f)(1)(ii)).

- *Safety and health considerations:*
  Properties of, and hazards presented by, the chemicals used in the process;
  Precautions necessary to prevent exposure, including engineering controls, administrative controls, and personal protective equipment;
  Control measures to be taken if physical contact or airborne exposure occurs;
  Quality control for raw materials and control of hazardous chemical inventory levels; and,
  Any special or unique hazards (29 CFR 1910.119(f)(1)(iii)).

- *Safety systems and their functions.* For example, interlocks and fire detection or suppression systems (29 CFR 1910.119(f)(1)(iv)).

- *Process hazard analysis.* The process hazard analysis is a thorough, orderly, systematic approach for identifying, evaluating, and controlling the hazards of processes involving highly hazardous chemicals. Employers covered by the PSM standard must perform an initial process hazard analysis (hazard evaluation) on all processes covered by the standard (29 CFR 1910.119(d) & (e)). The process hazard analysis methodology selected must be appropriate to the complexity of the process and must identify, evaluate, and control the hazards involved in the process.

  First, employers must determine and document the priority order for conducting process hazard analyses based on a rationale that includes such considerations as the extent of the process hazards, the number of potentially affected workers, the age of the process, and the operating history of the process (29 CFR 1910.119(e)). All process hazard analyses must be updated and revalidated, based on their completion date, at least every five years (29 CFR 1910.119(e)(6)).

  The employer must use one or more of the following methods, as appropriate, to determine and evaluate the hazards of the process being analyzed:
  - What-if,
  - Checklist,
  - Hazard and operability study (HAZOP),
  - Failure mode and effects analysis (FMEA),
  - Fault tree analysis, or
  - An appropriate equivalent methodology (29 CFR 1910.119(e)(2)).

  Whichever method(s) is used, the process hazard analysis must address the following:
  - The hazards of the process;
  - The identification of any previous incident that had a potential for catastrophic consequences in the workplace;
  - Engineering and administrative controls applicable to the hazards and their interrelationships, such as appropriate application of detection methodologies to provide early warning of releases. Acceptable detection methods might include process monitoring and control instrumentation with alarms, and detection hardware such as hydrocarbon sensors;
  - Consequences of failure of engineering and administrative controls;
  - Facility siting;
  - Human factors; and,
  - A qualitative evaluation of a range of the possible safety and health effects on workers in the workplace if there is a failure of controls (29 CFR 1910.119(e)(3)).

The process hazard analysis must be performed by a team with expertise in engineering and process operations, and that the team must include at least one worker who has experience and knowledge of the process being evaluated. Also, one member of the team must be knowledgeable in the specific analysis methods being used (29 CFR 1910.119(e)(4)).

The employer must establish a system to promptly address the team's findings and recommendations; ensure that the recommendations are resolved in a timely manner and that the resolutions are documented; document what actions are to be taken; develop a written schedule of when these actions are to be completed; complete actions as soon as possible; and communicate the actions to operating, maintenance, and other workers whose work assignments are in the process and who may be affected by the recommendations or actions (29 CFR 1910.119(e)(5)).

Employers must keep on file and make available to OSHA, on request, process hazard analyses and updates or revalidation for each process covered by PSM, as well as the documented resolution of recommendations, for the life of the process (29 CFR 1910.119(e)(7)).

- *Maintenance program.* Facilities covered by 29 CFR 1910.106 are required to establish maintenance and operating practices in accordance with established procedures which will tend to control leakage and prevent the accidental escape of flammable liquids (29 CFR 1910.106(h)(8)(i)). Additionally, all plant fire protection facilities must be adequately maintained and periodically inspected and tested to ensure that they are always in satisfactory operating condition and will serve their purpose in an emergency (29 CFR 1910.106(h)(6)(iv)). When necessary to do maintenance work in a flammable liquid processing area, the work must be authorized by a responsible representative of the employer (29 CFR 1910.106(h)(7)(ii)(a)). OSHA requirements for maintenance and repairs involving hot work and electrical wiring and equipment are addressed in 29 CFR 1910.106(h)(7)(ii)(b)&(h)(7)(iii).

  Maintenance procedures must be in place and adequate before introducing highly hazardous chemicals to a process in a PSM covered facility (29 CFR 1910.119(i)(2)(ii)).
  PSM covered facilities must perform inspection, testing, and repairs to ensure the safe functioning of process equipment (29 CFR 1910.119(j)(4).

  PSM covered facilities must ensure that inspection and testing is performed on process equipment, using procedures that follow recognized and generally accepted good engineering practices (29 CFR 1910.119(j)(4)(ii)). The frequency of inspections and tests of process equipment must conform with manufacturers' recommendations and good engineering practices, or more frequently if determined to be necessary by prior operating experience (29 CFR 1910.119(j)(4)(iii)). Each inspection and test on process equipment must be documented, identifying the date of the inspection or test, the name of the person who performed the inspection or test, the serial number or other identifier of the equipment on which the inspection or test was performed, a description of the inspection or test performed, and the results of the inspection or test (29 CFR 1910.119(j)(4)(iv)).

  Equipment deficiencies outside the acceptable limits defined by the process safety information must be corrected before further use. In some cases, it may not be necessary that deficiencies be corrected before further use, as long as deficiencies are corrected in a safe and timely manner, when other necessary steps are taken to ensure safe operation (29 CFR 1910.119(j)(4)(v)). The employer also must ensure that maintenance materials, spare parts, and equipment are suitable for the process application for which they will be used (29 CFR 1910.119(j)(6)(iii)).

- *Incident investigations.* The employer should investigate incidents that happen in the workplace, including near misses, to identify and correct hazardous situations, to preclude a catastrophic or fatal

event. Facilities subject to the PSM standard must initiate an incident investigation no later than 48 hours after occurrence, for each incident which resulted in, or could have resulted in a catastrophic release of highly hazardous chemical in the workplace. The employer must establish a system for implementing corrective actions (29 CFR 1910.119(m)).

- *Contractor Safety.* The requirements of the PSM standard in covered facilities also apply to contractors performing maintenance or repair, turnaround, major renovation, or specialty work on or adjacent to a covered process. (29 CFR 1910.119(f)(4) & (h)). It does not apply, however, to contractors providing incidental services that do not influence process safety, such as janitorial, food and drink, laundry, delivery, or other supply services.

  Employer responsibilities. When selecting a contractor, the employer must:
  - Obtain and evaluate information regarding the contract employer's safety performance and programs.
  - Inform contract employers of the known potential fire, explosion, or toxic release hazards related to the contractor's work and the process.
  - Explain to contract employers the applicable provisions of the emergency action plan.
  - Develop and implement safe work practices to control the presence, entrance, and exit of contract employers and contract employees in covered process areas.
  - Evaluate periodically the performance of contract employers in fulfilling their obligations; and,
  - Maintain a contract employee injury and illness log related to the contractor's work in the process areas (29 CFR 1910.119(h)(2)).

  Contract employer responsibilities. The contract employer must:
  - Ensure that contract employees are trained in the work practices necessary to perform their job safely;
  - Ensure that contract employees are instructed in the known potential fire, explosion, or toxic release hazards related to their job and the process, and in the applicable provisions of the emergency action plan;
  - Document that each contract employee has received and understood the training required by the standard by preparing a record that contains the identity of the contract employee, the date of training, and the means used to verify that the employee understood the training;
  - Ensure that each contract employee follows the safety rules of the facility including the required safe work practices required in the operating procedures section of the standard; and
  - Advise the employer of any unique hazards presented by the contract employer's work (29 CFR 1910.119(h)(3)).

C. Engineering Controls to Prevent Equipment Ruptures

- *Fire Detection and Suppression Systems.* Fires can be controlled or prevented by installing automatic fire detection and suppression systems at critical points within production areas such as tank storage areas and ethanol load-out areas.

- *Electrical Equipment and wiring.* Use of electrical equipment and wiring that is rated for the specific hazardous (classified) location (e.g., Hazard Class I).

- *Pressure Relief.* Equipment with design features such as relief valves or rupture discs preclude/limit the occurrence of ruptures by relieving excess pressure. ASME B31.3, Process Piping, provides the presumptive pipe and corrosion resistance specifications that must be met for relief system piping (29 CFR 1910.106(c)(1)(i)).

Hazards that lead to equipment ruptures are discussed in III.B.

D. Safe Work Practices to Prevent Equipment Ruptures

- *Monitoring.* Routinely inspecting tanks, piping and other equipment at regular intervals to identify cracks, leakages, corrosions, and worn parts that could potentially result in ruptures. Inspecting equipment systems to ensure that they are functioning properly, for example, monitoring equipment pressure and temperature, and establishing procedures for taking appropriate actions if the pressure/temperature is not within the normal limits of operation for the equipment.

- *Maintenance Program.* An adequate maintenance program will establish the procedures for routine maintenance and provide the resources for sustaining equipment (repairs/replacement) in optimal working condition at all times (IV.A, mechanical integrity; and IV.B, maintenance program).

E. Engineering Controls for Combustible Dust Hazards

Several different engineering controls are available to prevent hazards and exposure to combustible dusts (III.C). Examples of some, but not all, of the engineering controls that ethanol manufacturing facilities could use are listed below. A more complete listing of available and recommended engineering controls can be found in industry guidance documents, NFPA consensus standards, and OSHA compliance guidelines (e.g., OSHA, 2005; OSHA, 2011a; FM Global, 2009a, 2009b, 2010a, 2010b; Combustible Dust: Safety and Injury Prevention Instructors Manual (2008); NFPA 61, NFPA 69). Again, facility-specific factors ultimately determine the most appropriate combination of controls.

- *Ignition controls.* Typical process areas involving the presence of combustible dusts are classified as Class II hazardous locations according to the NEC (29 CFR 1910.307(c)(2)(i)). A Class II hazardous location is an area where the dusts suspended in air are capable of causing an explosion. The use of electrical equipment and wiring classified for Class II locations is essential to preventing electrical devices from becoming sources of ignition. Another common ignition source is overheated bearings on belt conveyors and bucket elevators. This source can be effectively controlled by installing temperature sensors on bearings and other related controls, like belt alignment sensors. These monitors can have low- and high-alarm settings interlocked with audible alarms, automated shutdowns, and other actions based on the detection of increasingly unsafe conditions. Additionally, effective grounding and bonding should be considered on process equipment prone to electrostatic discharge during routine operation.

- *Dust controls.* An effective strategy for preventing combustible dust incidents is to prevent dust from being released, preclude the accumulation of dust that can be ignited, or that can provide additional fuel for a secondary explosion. This can be accomplished by designing and maintaining equipment (e.g., chutes, transfer points, bucket elevators, conveyor belts) to be as dust-tight as possible to minimize dust generation. Highly efficient dust collection and aspiration systems are critical to effectively controlling dust. If unexpected leaks or emissions occur, fast response and remediation will minimize the quantity of dust released.

- *Equipment design.* Engineering design that incorporates safety measures is vital to maintaining a safe workplace. For example, under the grain handling standard, direct-heat grain dryers installed after March 30, 1988 must be located outside the grain elevator; located in an area inside the grain elevator

protected by a fire or explosion suppression system; or, located in an area inside the grain elevator which is separated from other areas of the facility by construction having at least a one hour fire-resistance rating (29 CFR 1910.272(p)(2)). Safeguards, monitoring systems and controls that are required (at a minimum) for bucket elevators are discussed in 29 CFR 1910.272(q).

- *Other controls.* Numerous other engineering controls have been designed specifically to prevent combustible dust explosions or to mitigate their consequences, and NFPA has developed consensus standards that specifically address controls most suitable for agricultural dusts (NFPA 61).

    - *Explosion suppression systems.* Automatic explosion suppression systems (NFPA 69) can be used to detect pressure rises indicative of explosions and promptly suppress these events, for example, by injecting large volumes of a suppression agent (suppressant) into the operation being controlled. These systems are most commonly applied to dust collectors, milling rooms, and other areas believed to present the greatest risk for explosions.

    - *Fire detection and suppression systems*. Fire detection and suppression systems are common in dryers, dust collectors, and other operations prone to fire. In the case of dryers, sensors placed inside dryers and their outlets are used to detect elevated and rapidly increasing temperatures, with the measured levels triggered to various actions of increasing severity, such as audible alarms, steam suppression, and full water deluge.

      Similarly, other automatic systems can be used to detect sparks and smoldering materials in certain dust-laden air streams, with detections triggering fire suppression at downstream locations. These devices are particularly useful in ductwork on the outlet of unit operations (e.g., dryers, mills) suspected of causing sparks or smoldering material.

    - *Explosion relief venting.* Yet another commonly encountered feature is explosion-relief venting, which is designed to control deflagration pressure (NFPA 68) by venting combustion products from an enclosure (e.g., dust collector, bucket elevator) to a safe location, rather than having a confined deflagration result in a devastating explosion. Should pressure inside the equipment rise rapidly and unexpectedly, explosion relief panels are designed to open to safely relieve the developing pressure and any material discharged from a deflagration outside to a safe location. This minimizes structural and mechanical damage, and protects workers from severe injuries and/or fatalities that could have occurred in an explosion.

F. Safe Work Practices for Combustible Dust Environments

Various safe work practices are commonly used to help prevent dust-related fires and explosions in general industry, and many of these would also apply to ethanol manufacturing facilities. Examples of such administrative controls are listed below (OSHA, 2011a; Combustible Dust: Safety and Injury Prevention Instructors Manual (2008)).

- *Housekeeping.* One of the most important administrative controls for combustible dust is an effective housekeeping program. These programs must establish the frequency and methods to best reduce dust accumulations on ledges, floors, equipment, and other exposed surfaces (29 CFR 1910.272(j)(1)). For priority housekeeping areas, employers must immediately remove any grain dust accumulation that exceeds 1/8th of an inch or demonstrate that equivalent protection is provided through the housekeeping program (29 CFR 1910.272(j)(2)(ii)). Priority housekeeping include areas near grain handling equipment; for example, floor areas within 35 feet of inside

bucket elevators, floors of enclosed areas containing grinding equipment, and enclosed areas with grain dryers (29 CFR 1910.272(j)(2)(i)).

The methods used for housekeeping should be based on the assessed hazard potential. For instance, employers might determine that only non-sparking tools (e.g., soft bristle brooms, bronze hand tools) and intrinsically safe hazard class II rated vacuums are acceptable in certain facility areas. The use of compressed air to blow dust from surfaces is only permitted when all machinery that presents an ignition source in the area is shut down, or all other known potential ignition sources in the area are removed or controlled (29 CFR 1910.272(j)(3)). Water or steam washes might also be preferred in some instances. Frequent housekeeping audits should be conducted to assess the effectiveness of cleaning procedures, measure dust accumulation rates, and identify hidden accumulations of combustible dusts (e.g., above drop ceilings).

- *Safety programs.* Another essential element of preventing combustible dust hazards is by developing and implementing safety programs required by other OSHA standards, such as hot work programs, confined space entry permit programs, and lockout-tagout programs (IV.U). These should all specifically acknowledge combustible dust hazards associated with performing hot work or conducting other maintenance activity in enclosed spaces.

- *Training.* Many dust explosions result from workers simply not being aware of a hazardous situation. This is a root cause that can readily be prevented through effective training programs. Thorough initial and refresher training on combustible dust hazards is essential for all workers whose jobs involve working with or near these materials. For example, workers who conduct routine housekeeping activities need to learn what types of cleaning equipment should be used and avoided in different production areas(e.g., use of non-sparking tools, dust ignition-proof vacuums). The employer must provide training to workers at least annually and when changes in job assignment will expose them to new hazards. This training must include general safety precautions for the facility, including recognizing and preventing the hazards associated with dust accumulations and common ignition sources. In addition, it must include specific procedures associated with the employee's job including cleaning procedures for grinding equipment, clearing procedures for choked legs, housekeeping procedures, hot work procedures, preventative maintenance procedures, and lockout/tagout procedures.

- *Facility dust hazard assessment.* Past incidents have revealed that company representatives, managers, and workers are often not aware of existing dust explosion hazards and effective mitigation measures. In these cases, a systematic evaluation of potential dust explosion hazards associated with all processes, equipment, and work areas could have helped identify dangerous situations before major incidents occurred. A periodic review is necessary to identify new hazards and/or safety measures that may not be functioning effectively, and to implement effective measures.

- *Management commitment.* Previous incident investigations at selected facilities have identified a need for stronger commitment from management to prevent combustible dust hazards. For example, some facilities experienced fires and explosions where similar events had previously occurred but had not been fully investigated.

- *Permit System*. The employer shall institute an effective permit system that prevents workers from performing operations without complying with the required safety precautions. For instance, when required by 29 CFR 1910.272, a hot work permit must be issued (29 CFR 1910.272(f)), certifying that the fire prevention and control measures specified in 29 CFR 1910.252(a) have been met before starting work.

Similarly, when required by 29 CFR 1910.272, a permit must be issued for workers entering bins, silos or tanks certifying that the precautions contained in 29 CFR 1910.272(g) (e.g., isolation of hazardous energy, atmospheric testing, and the use of the right type of respirator when needed) have been implemented.

- *Maintenance Program.* Employers can further prevent hazards through routine inspection, testing, and maintenance of process equipment to keep it in optimal working condition. The grain handling standard specifies minimum requirements for preventative maintenance in facilities it covers, which includes conducting regularly scheduled inspections, lubrication, correcting malfunctioning dust collection systems, and maintaining records of each inspection (29 CFR 1910.272(m)).

- *Incident Investigation.* Investigation of all incidents that happen in the workplace, including near misses, to correct hazardous situations in order to prevent a catastrophic or fatal event from occurring.

G. Engineering Controls for Engulfment Hazards

Engulfment hazards (III.D) at ethanol manufacturing facilities can be avoided through various approaches.

- *Equipment design.* Silos, bins, and other storage vessels can be equipped with design features that reduce the need for workers to enter the equipment in the first place. These features, which are particularly important for grain elevator facilities that handle corn that is more prone to spoilage, are thoroughly documented in the literature (e.g., NIOSH, 1987; Purdue University, 2011).

H. Safe Work Practices for Engulfment Hazards

Administrative controls are particularly effective for preventing engulfment hazards at ethanol manufacturing facilities (OSHA, 2011a; Purdue University, 2011).

- *Operating procedures.* Above all else, operating procedures that specifically prohibit employees from entering stored grain—whether in silos, truck beds, or other locations—can effectively eliminate the hazard. Operating procedures must prohibit workers from "walking down the grain" and performing similar activities expected to make grain flow (29 CFR 1910.272(g)(1)(iv)). Workers are forbidden from entering onto or below a grain bridging condition or anywhere that a grain accumulation could fall and engulf a worker, for example, grain built up along the side of the bin (29 CFR 1910.272(g)(6)). Measures should also be implemented to ensure that workers do not need to work around the perimeter of tall storage piles of solid co-products.

- *Training.* Every worker must be provided with the required safety training before they start work, at least annually and whenever changes in job assignment (29 CFR 1910.272(e)) or processes (e.g., equipment, chemicals) will expose them to new hazards. Employees working with grain need to be properly trained in handling, storing, and processing these materials. Training must at least cover general safety precautions and specific procedures and safety practices applicable to their tasks, including any special assignments, such as, bin entry. The majority of entrapment and engulfment incidents result when workers enter bins in unsafe conditions; therefore, workers must be trained on the hazards they face when performing tasks inside silos, bins and other grain storage units. The training must address engulfment, mechanical hazards and means of avoiding these hazards. Workers should not be allowed to perform tasks until they can demonstrate a complete knowledge of all equipment involved in their work activities.

- *Permits.* In grain handling facilities where workers must enter bins, silos, or tanks, safe work entry permits must be issued before entry (unless the employer or employer's representative responsible for authorizing the permit would be present for the entire duration of the work). The permit must certify that the standard's required precautionary measures are implemented before workers are allowed to enter the silo, bin, or tank (29 CFR 1910.272(g)(1)(i)).

I. Personal Protective Equipment for Engulfment Hazards

- *Body harness and lifeline.* Workers who must enter grain storage structures with engulfment hazards must be equipped with body harnesses and lifelines, or a boatswain's chair (29 CFR 1910.272(g)(2)), with a designated observer present who is in communication with the worker at all times and can assist with rescue procedures in the event of an unexpected engulfment (29 CFR 1910.272(g)(3)). The lifeline must be long enough so that a worker does not sink further than waist-deep in grain. If the required PPE poses a greater hazard or is not feasible, employers must use alternate means that prevent workers from sinking beyond waist deep in grain (29 CFR 1910.272(g)(2)).

J. Engineering Controls for Hazardous Noise Levels

Safety measures to minimize workers exposure to hazardous noise levels in grain processing areas include (excerpt from Cralley, 1985):

- *Grain unloading areas.* Locating pneumatic blowers separately from work areas or enclosed in acoustic booths.

- *Grain elevators.* Using quieter conveyor equipment, shutting off conveyor systems when not in use, and minimizing the use of compressed air (29 CFR 1910.272(j)(3)). Using low-speed, high-volume conveyors can also greatly reduce noise and dust. If such methods cannot be used effectively, it may be necessary for operators to monitor grain flow from inside acoustical booths.

- *Grain processing.* Reducing noise levels at their source through engineering controls may be extremely difficult because of the large size, sanitation requirements, and number of machines in a typical facility. However, in some workers can be separated from noise exposures by isolation techniques. Pneumatic blowers, air compressors, and other extremely loud noise sources should be located in separate rooms away from major work areas. Control panels should be consolidated in a centrally located acoustically treated control booth, which functions both as a work station and relief area from noise exposure.

Additional information on noise exposure controls is discussed in the OTM, Section III, Chapter 5, Noise.

K. Hearing Conservation Program

OSHA requires employers in the general industry to administer a continuing, effective hearing conservation program, as described in paragraphs (c) through (o) of 29 CFR 1910.95, whenever employee noise exposures equal or exceed an 8-hour time-weighted average (TWA) sound level of 85 decibels measured on the A scale (dBA) or, equivalently, a dose of fifty percent (29 CFR 1910.95(c)).

A continuing, effective hearing conservation program is also required in the construction industry when sound levels exceed the values shown in Table D-2 of 29 CFR 1926.52. This table includes a permissible exposure of 90 dBA for an 8-hour TWA.

Additional information on noise exposure controls is discussed in the OTM, Section III, Chapter 5, Noise.

L. Hearing Protection Devices

OSHA requires employers to provide workers with hearing protection devices whenever noise exposure levels equals or exceeds OSHA's specifications, unless the costs of engineering and/or administrative controls are less than the cost of an effective hearing conservation program(29 CFR 1910.95; 29 CFR 1926.52; CPL 02-00-148, OSHA's Field Operations Manual, p. 4-41).

Additional information on noise exposure controls is discussed in the OTM, Section III, Chapter 5, Noise.

M. Engineering Controls for Hazardous Substances

In general, the standards in subparts Z of 29 CFR 1910 and 29 CFR 1926 require employers to use engineering and administrative controls, to the extent feasible, to control worker exposure above the specified PEL. Engineering controls include:

- *Ventilation*. Industrial ventilation generally involves the use of supply and exhaust ventilation to control emissions, exposures, and chemical hazards in the workplace (OSHA Technical Manual [OTM], Section III, Chapter 3, Ventilation Investigation, OSHA 1999).

- *Enclosures*. Emission sources may be enclosed to protect workers from exposure, for example, processing toxic chemicals in closed piping systems or hoods.

- *Substitution*. Hazardous chemicals or processes should be replaced with less hazardous chemicals or processes when feasible.

- *Elimination*. Hazardous chemicals and/or processes should be removed from the operation when practicable.

N. Safe Work Practices to Protect Workers from Hazardous Substances

- *Hazard Communication Standard (HCS).* The requirements of the HCS (29 CFR 1910.1200) must be implemented (OSHA's Hazard Communication Page) to protect workers from exposure to hazardous chemicals (III.F). These include:

    - *Hazard Communication Program*. A site specific Hazard Communication Program must be implemented for each applicable workplace, this includes employee training (29 CFR 1910.1200(e)).
    - *Material Safety Data Sheets (MSDSs) or Safety Data Sheets*[4] *(SDSs).* MSDSs/SDSs for hazardous substances must contain information required by the HCS, for example, it must document physical and health hazards associated with exposure and the appropriate controls that must be utilized in the work place to protect workers. The MSDS/SDS must

[4] OSHA's Hazard Communication standard was revised in 2012. Safety Data Sheets (SDSs) will replace MSDSs. SDSs have a standardized 16-section format with specific information required in each section. Manufacturers and importers have until June 1, 2015 to replace MSDSs with SDSs; until then either MSDSs or SDSs may be received by employers.

be easily accessible to workers and workers must receive the necessary training, including how to use the hazard information (29 CFR 1910.1200(g)).
    - *Container labeling*. The HCS requires hazardous chemicals to display the appropriate labeling information and for workers to receive training that explains the label information (29 CFR 1910.1200(f)).
    - *Employee training.* Employers must train workers on methods that may be used to detect the presence of hazardous chemicals in the work area; the hazards of the chemicals in the work area; the safety measures that have been implemented to protect them from hazardous chemicals in the workplace, including appropriate work practices, emergency procedures, and personal protective equipment to be used; and the details of the employers hazard communication program (29 CFR 1910.1200(h)(3)).

- *PSM covered facilities*. The PSM standard requires employers to have process safety information for highly hazardous chemicals (29 CFR 1910.119(d)). A highly hazardous chemical means a substance possessing toxic, reactive, flammable (e.g., ethanol, gasoline), or explosive properties and specified by 29 CFR 1910.119(a)(1). The PSM standard covers toxic and reactive highly hazardous chemicals which are listed with their threshold quantities in Appendix A of 29 CFR 1910.119 (e.g., sulfur dioxide (1,000 pounds); anhydrous ammonia (10,000 pounds); and anhydrous hydrochloric acid (5,000 pounds)). The process safety information must include information on the hazards of the highly hazardous chemicals used or produced by the process, information on the technology of the process, and information on the equipment in the process.

  Information on the hazards of the highly hazardous chemicals in the process must consist of at least the following:
    - Toxicity,
    - Permissible exposure limits,
    - Physical data,
    - Reactivity data,
    - Corrosivity data, and
    - Thermal and chemical stability data, and hazardous effects of inadvertent mixing of different materials (29 CFR 1910.119(d)(1)(i)).

  Information on the technology of the process must include at least the following:
    - A block flow diagram or simplified process flow diagram,
    - Process chemistry,
    - Maximum intended inventory,
    - Safe upper and lower limits for such items as temperatures, pressures, flows or compositions, and
    - An evaluation of the consequences of deviations, including those affecting the safety and health of employees (29 CFR 1910.119(d)(2)(i)).

Where the original technical information no longer exists, such information may be developed in conjunction with the process hazard analysis in sufficient detail to support the analysis.

Information on the equipment in the process must include the following:
    - Materials of construction,
    - Piping and instrument diagrams (P&IDs),
    - Electrical classification,
    - Relief system design and design basis,
    - Ventilation system design,
    - Design codes and standards employed,

- Material and energy balances for processes built after May 26, 1992, and
- Safety systems (e.g., interlocks, detection, or suppression systems) (29 CFR 1910.119(d)(3)(i).

The employer shall document that equipment complies with recognized and generally accepted good engineering practices (29 CFR 1910.119(d)(3)(ii)). For existing equipment designed and constructed in accordance with codes, standards, or practices that are no longer in general use, the employer shall determine and document that the equipment is designed, maintained, inspected, tested, and operated in a safe manner (29 CFR 1910.119(d)(3)(iii)).

The compilation of the above described process safety information provides the basis for identifying and understanding the hazards of a process and is necessary in developing the process hazard analysis and may be necessary for complying with other provisions of PSM such as management of change and incident investigations.

O. Personal Protective Equipment (PPE) to Protect Workers from Hazardous Substances

Whenever workers' exposure to hazardous chemicals cannot be eliminated or reduced to acceptable/safe levels, employers must select and provide personal protective equipment of the appropriate type to affected workers, including training and implementation of any required safety program, such as the respiratory protection program. For example, when there are pesticides or fumigants used in the workplace that can penetrate the skin, only trained workers using clean, well-maintained PPE (e.g., protective clothing, gloves) resistant to the chemical's penetration can be allowed to handle the pesticides or fumigants.

P. Engineering Controls for Confined Spaces

The safety and health of workers entering confined spaces in grain handling facilities is addressed by both the Grain Handling Facilities standard, 29 CFR 1910.272 and the Permit Required Confined Spaces standard, 29 CFR 1910.146. However, confined space work, such as grain bin entry, that is regulated by 29 CFR 1910.272, is not subject to the provisions of 29 CFR 1910.146, as long as the provisions of 29 CFR 1910.272 protect workers against all the hazards within the grain bins (OSHA Letter of Interpretation: Questions regarding the PRCS standard, 1910.146, and the Grain Handling standard, 1910.272. [02/08/2005]).

Refer to Appendix C for safety and health information on above ground storage tanks.

- *Atmospheric Testing.* Atmospheric testing (pre-entry testing) is conducted to assess the oxygen content, potential explosive atmospheres, and to detect any hazardous gases before entering into confined spaces such as grain storage units. Continuous atmospheric testing and monitoring is done while workers are in the confined space. Supplemental ventilation or respirator use may also be required, depending on the gas concentrations measured.

- *Ventilation.* Continuous ventilation combined with initial purging and local exhaust ventilation can be implemented to ensure that the atmospheric conditions are safe for workers. If unable to ensure safe air quality, then workers should don appropriate respirators.

- *Barriers.* Barriers are used to prevent external hazards from harming confined space entrants (OSHA, 2011a).

Q. Safe Work Practices for Confined Space Hazards

- *Warning signs*. Warning signs at confined space entry points are used to discourage unauthorized entry.

- *Permits.* Confined space programs specify the safety procedures that must be implemented before a confined space entry permit can be obtained.

- *Housekeeping.* For example, housekeeping programs for grain elevators shall address fugitive grain dust accumulations at priority housekeeping areas. These include floor areas within 35 feet (10.7 m) of inside bucket elevators (29 CFR 1910.272(j)(2)).

- *Maintenance Program*. Regularly scheduled inspections of at least the mechanical and safety control equipment associated with dryers, grain stream processing equipment, dust collection equipment including filter collectors, and bucket elevators (29 CFR 1910.272(m)(1)(i)). The employer must promptly correct dust collection systems which are malfunctioning or which are operating below designed efficiency. Additionally, the employer must promptly correct, or remove from service, overheated bearings and slipping or misaligned belts associated with inside bucket elevators (29 CFR 1910.272(m)(2)).

R. Personal Protective Equipment for Confined Space Hazards

If needed, the appropriate types of personal protective equipment (PPE) for the identified hazards must be provided to confined space entrants. PPE may include a body harness and lifeline.

S. Engineering Controls for Motor Vehicle Hazards (e.g., loading, unloading, operating)

- *Grounding and bonding.* Grounding and bonding precautions prevent static electricity discharges that could serve as a source of ignition, e.g., when flammable liquids or combustible dusts are present during loading/unloading operations, from motor vehicles in product load-out areas.

- *Hazardous Classified Location.* Use of equipment and wiring rated for the hazardous classified location, including intrinsically safe tools to eliminate sources of ignition.

- *Lightning Early Warning Systems.* Lightning early warning systems are used to provide advance warning of lightning approaching an area. This will alert workers to suspend loading and unloading of flammable and/or combustible dust materials in advance of an impending lightning storm.

- *Road Maintenance*. It is crucial to maintain roads in good condition around the workplace to facilitate the safe flow of traffic.

T. Safe Work Practices for Motor Vehicle Operation

- *Preventive Maintenance Program.* Inspecting and maintaining vehicles in optimal working condition is essential to ensure that they function properly.

- *Pedestrian safety.* Planning travel routes to avoid intersections between truck routes and frequently-used pedestrian walkways wherever possible and clearly marking truck access routes

and crosswalks. Alarm systems, signs, and barricades can be used to warn pedestrians of trucks pulling out or into parking areas, loading or unloading zones, etc.

- *Speed limits.* Setting and enforcing safe speed limits to manage safe movement of traffic for truck deliveries.

- *Protecting equipment, pipes, etc.* It is critical to carefully plan transportation routes away from equipment and pipes to avoid collisions that could cause serious injuries or death to workers, equipment ruptures, facility damage, etc.

- *Awareness campaigns.* Launching awareness campaigns to target unsafe driving practices, such as driving while fatigued or under the influence of alcohol and drugs.

- *Loading and unloading.* Establishing procedures for the safe loading and unloading of motor vehicle contents. For example, not allowing vehicles to idle during loading or unloading operations, prohibiting the loading or unloading of motor vehicles to occur during an electrical storm, and establishing lightning approach distances to stop loading and unloading operations during such storms. Pedestrians must be prohibited in loading and unloading areas.

- *Repairs.* No repairs or maintenance activities should be done on trucks within the loading or unloading areas; disabled vehicles should be towed.

- *Road conditions.* Transporting goods in inclement weather should be avoided.

- *Ignition Sources.* Sources of ignition (e.g., smoking, lightning, cutting, welding, hot surfaces) in areas where flammable vapors may be present must be eliminated or controlled (29 CFR 1910.106(b)(6)). For example, smoking and open flames inside or near vehicles should be prohibited. Designated smoking areas must be at safe distances from motor vehicles and flammable liquid processing or storage areas.

- *Training.* A driver training program should be established to promote safe driving.

- *Scheduling.* Driver schedules should be set to allow for breaks, rest periods and ensure compliance with the Department of Transportation's Hours of Service Regulation.

U. Lockout/Tagout of Hazardous Energy

Energy sources found throughout ethanol processing facilities include electrical, mechanical, hydraulic, pneumatic, chemical, thermal or other sources in machines and equipment which can be hazardous to workers. During the servicing and maintenance of machines and equipment, the unexpected startup or release of stored energy could cause injury to employees. Workers servicing or maintaining machines or equipment may be seriously injured or killed if hazardous energy is not properly controlled. Injuries resulting from the failure to control hazardous energy during maintenance activities can be serious or fatal. Injuries may include electrocution, burns, crushing, cutting, lacerations, amputations, fractures and others.

Failure to control hazardous energy accounts for nearly 10 percent of the serious accidents in many industries. Proper Lockout/Tagout (LOTO) practices and procedures protect workers from the release of hazardous energy. OSHA's Lockout/Tagout fact sheet describes the practices and procedures necessary to disable machinery or equipment to prevent the release of hazardous energy.

The OSHA standard for the Control of Hazardous Energy (Lockout/Tagout), 29 CFR 1910.147, specifies that when other general industry standards (29 CFR 1910) require the use of lockout or tagout, they shall be used and supplemented by the procedural and training requirements of 29 CFR 1910.147 (29 CFR 1910.147(a)(3)(ii)). The LOTO standard establishes the employer's responsibility to protect workers from hazardous energy and to train each worker to know, understand, and be able to follow the applicable provisions of the hazardous energy control procedures in their workplace (Control of Hazardous Energy (Lockout/Tagout), Safety and Health Topics Page, OSHA, 2011e.

The requirement to utilize LOTO procedures in grain storage structures are specified in 29 CFR 1910. 272(g)&(h). It states that all mechanical, electrical, hydraulic, and pneumatic equipment that presents a danger, particularly grain-moving equipment, must be de-energized (turned off) and disconnected, locked out and tagged, or blocked off, or otherwise prevented from operating by other equally effective means, before permitting workers to enter (29 CFR 1910.272(g)(1)(ii)&(h)(2)(i); Worker Entry into Grain Storage Bins fact sheet, OSHA 2010).