IV. SAFE WORK PRACTICES, ENGINEERING CONTROLS, AND TRAINING NEEDS

A. INTRODUCTION

This section contains the practices recommended as a means of reducing accidents and injuries in grain elevators and feed mills. The recommendations are designed to make the workplace safer and to make workers and management aware of the hazards normally associated with these facilities. The recommendations are performance oriented where possible, stating the goal to be achieved. Successful methods of achieving the goal, and the criteria upon which the recommendations are based, are addressed where applicable.

B. DEFINITION OF TERMS

The following definitions are used for purposes of this document:

Bucket Elevator. A continuous conveyor belt with equally spaced buckets attached, which elevates and discharges material into a spout or other receiver. Elevation is usually vertical, although some bucket elevators are sloping. The main sections of a bucket elevator are usually referred to as the head, boot, and leg. The head is the top section of a bucket elevator where the drive is located and the material is discharged. The boot is the bottom section where material enters the bucket elevator and is picked up by the buckets. The leg is the section between the head and boot.

Choke Feeding. A condition of material buildup in a spout or hopper without stoppage of discharge flow. Choke feeding may be used to provide an even feeding rate or reduce grain breakage and dust generation.

Choked Condition. A condition of material buildup in spouts, hoppers, or equipment that results in stoppage of material flow in a conveying system.

Class II Locations. Locations that are hazardous because of the presence of combustible dust. Class II locations include the following [49, 50]:

- Class II, Division 1--A Class II, Division 1 location is a location: (1) In which combustible dust is or may be in suspension in the air, under normal operating conditions, in quantities sufficient to produce explosive or ignitable mixtures; or (2) where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitable mixtures to be produced, and might also provide a source of ignition through simultaneous failure of electrical equipment, operation of protective devices, or from other causes; or (3) in which combustible dusts of an electrically conductive nature may be present.

- Class II, Division 2--A Class II, Division 2 location is a location: (1) in which combustible dust will not normally be in suspension in the air in quantities sufficient to produce explosive or ignitable mixtures, and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatuses; or (2) in which dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment, and dust accumulations resulting therefrom may be ignitable by abnormal operation or failure of electrical equipment or other apparatuses.

Combustible Dust. A dust which may explode or burn when subjected to a source of ignition in the presence of atmospheric oxygen.

Confined Space. A space which by design has limited openings for entry and exit, unfavorable natural ventilation which could contain or produce dangerous air contaminants, and which is not intended for continuous employee occupancy. Confined spaces include but are not limited to storage tanks, compartments of ships, process vessels, pits, silos, vats, degreasers, reaction vessels, boilers, ventilation and exhaust ducts, sewers, tunnels, underground utility vaults, and pipelines.

Dust. Any finely divided solid material formed by disintegration processes whether product or waste.

Explosion. Combustion of a dust, vapor, or gas which results in the rapid development of heat and pressure beyond the confinement capability of an enclosed space.

Feed Mill. An establishment primarily engaged in manufacturing feed for animals.

Foreign Material. Any unwanted objects or materials inadvertently mixed with the grain or feed. Foreign materials may include nails, bolts, sticks, stones, dirt, and other similar items.

Grain Elevator. An establishment primarily engaged in the receipt, handling, storage, and shipment of grain (such as corn, wheat, oats, barley, and unpolished rice) and beans. Facilities may be classified as country elevators, inland terminals, or port terminals, or may be operated in support of grain-processing facilities.

Group G Atmospheres. Atmospheres containing flour, starch, or grain dust.

Headhouse. A portion of a grain elevator used to house grain-handling equipment. The headhouse may include equipment to elevate, weigh, sample, and clean grain; to direct grain to bins or conveyors, or to perform other operations. The terms "headhouse" and "workhouse" are usually interchangeable, although sometimes the section of the workhouse that extends above the bins is referred to as the headhouse because the head pulleys of the bucket elevators are located there.

Hot Work. Work involving electric or gas welding, cutting, brazing, or similar heat-producing operations, as well as work such as grinding, which produces a potential source of ignition.

Jogging. Repeated starting of drive motors in an attempt to clear choked equipment.

Lagging. A covering on drive pulleys used to increase the coefficient of friction between the pulley and the belt. Lagging may have a smooth or grooved surface and is usually installed on belt conveyor and bucket elevator head pulleys as well as flat belt power transmission pulleys.

Lower Explosive Limit (LEL). The minimum concentration of a flammable or combustible gas, vapor, or dust in air which will allow flame propagation.

Permissible Exposure Limit (PEL). The maximum amount of any airborne contaminant to which an employee may be exposed as listed in 29 CFR 1910 Subpart Z [49].

Permit. An authorization and approval in writing that specifies the location and the work to be performed, and certifies that all hazards have been evaluated by a qualified person and necessary protective measures have been taken to ensure the safety of each worker.

Qualified Person. A person, designated by the employer, capable (by reason of training and/or experience) of recognizing and evaluating exposure to unsafe conditions and specifying necessary controls and/or actions to ensure worker safety.

Scalper. Screening machinery used to remove foreign material larger than the grain or feed itself.

Tramp Metal. Any metallic objects or materials that are inadvertently mixed with the grain or feed. Tramp metal may include nails, bolts, wires, tools, or any other metallic items.

Tripper. A device used to divert grain or material from a conveyor belt into a bin opening, hopper spout, or machine.

Turnhead. A device that distributes or routes grain or material from one spout, bin hopper, or machine to two or more bins, spouts, or machines.

C. TRAINING

Occupational hazards are caused by the interaction between workplace, machines, and humans.

The value of employee training is recognized throughout industry. A safe operation largely depends upon employees who are properly informed and aware of the potential hazards. To be effective, training must be done by a knowledgeable person and must address safe performance of the assigned tasks as well as other relevant aspects of hazard recognition and control within the workplace [51-57]. The employer is responsible for establishing a training program commensurate with the tasks to be performed and safe work practices to be followed.

Personnel need to be made aware of the hazards of dust explosions, general hazards which may be encountered in grain elevators and feed mills, the specific hazards which may be encountered in the performance of their assigned tasks, and the necessary actions or precautions to be taken to prevent accidents. In addition to training for the equipment, machinery, and vehicles which the employee will operate or use to accomplish the assigned tasks, training should cover the use of personal protective equipment, emergency procedures, and other applicable work practices recommended in this report.

Training programs should include both general orientation sessions and on-the-job training. Safety orientation should include classroom sessions addressing safety rules and policies and a walk-through of the facility. After the employee has received a basic understanding of the operation and the hazards involved, on-the-job instruction including demonstrations and supervised participation in actual work practices should be provided. Training should not be considered complete until it has been demonstrated to the satisfaction of the employer, or the person designated by the employer to conduct the training, that the employee is able to perform the assigned tasks safely and is familiar with the precautions that must be taken in the workplace to prevent injuries. Retraining should be conducted as needed to ensure that workers are able to perform their duties in a safe manner.

Safety orientation programs should also be developed for contractor personnel. The program should address safety rules and policies, hazards associated with combustible dust, and other specific hazards that may be encountered in grain elevators and feed mills with which the contractor personnel may not be familiar.

D. SAFETY PROGRAM AND ENGINEERING CONTROLS

The first step in an effective safety program is management commitment. To reduce accidents, it is essential that management be fully committed to work safety and insist that all employees be involved. Employers are required by law to provide a place of employment free from recognized hazards. To achieve this end, management must ensure that hazards are identified and effective hazard controls are developed, implemented, and remain in continuous use [58, 59]. Persons responsible for safety in the facility should be clearly identified.

Identification of hazards and associated safe work practices can best be accomplished by conducting a system safety analysis of the facility and operations. Various techniques such as a "job safety analysis," which breaks jobs into a sequence of steps that can be more easily addressed, can be applied. Safety analyses can be performed informally; however, a formal approach which results in detailed operational procedures is usually most effective. Analysis should initially be accomplished on operations where experience indicates accidents and injuries are most likely to occur.

As a part of an effective safety program, management should:

- Ensure compliance with safety and health regulations
- Establish an effective training program
- Establish emergency preparedness plans
- Establish necessary controls for visitors and outside contractors
- Ensure that a comprehensive dust control program is developed and implemented
- Ensure that the safe work practices contained in the report are evaluated and applied where applicable

- Ensure that all equipment and machinery are in a safe operating condition, are capable of safely performing the job for which they are used, and are regularly maintained and inspected

- Ensure that adequate procedural controls are developed and implemented for hot work, confined space entry, and other potentially hazardous operations.

- Establish and enforce general safety rules. Rules should address use of smoking materials, alcohol, drugs, and weapons as well as policies covering use of protective equipment and accident reporting systems. Compliance with safety policies should be stipulated as a condition of employment.

Employee safety committees can be key elements of industrial safety programs. Committees typically meet periodically with management representatives to examine potential safety issues and recommend abatement procedures. Committee members may also perform safety inspections, review accident reports, and perform other safety-related functions.

E. EMERGENCY PLANNING

The value of emergency planning as a means of conserving life and property is generally recognized throughout industry [36, 60-62]. Timely and efficient action can mean the difference between a minor incident and a major catastrophe. Coordination with local emergency organizations is strongly recommended. Fire departments and rescue organizations in particular should be requested to tour facilities to become familiar with the particular problems that may be encountered and should also have an awareness of how to deal with a fire in a grain-handling facility.

Preplanning is needed to determine specific duties, responsibilities, and actions that should be taken to enhance worker safety during emergencies. Written procedures should be developed in accordance with 29 CFR 1910.38 [49] for fires, explosions, medical emergencies, and other emergencies or natural disasters that could reasonably occur. Other areas to be addressed and the specific content of the procedures should be determined by a qualified person on the basis of the facility size, conditions at the facility, and geographic location. Procedures may include provisions for limiting facility damage if this can be accomplished without additional risk; however, safety of personnel must take precedence. The procedures should include, but not be limited to, the following:

- Methods and responsibilities for reporting emergency conditions. Provisions for prompt reporting of emergencies should always be a primary consideration. Protective signaling systems can be provided or emergencies can be reported over intercoms or public address systems. Telephones or radios may also be used to report emergencies to a central, continuously manned location.

- Methods and responsibilities for contacting emergency agencies. Emergency phone numbers should be posted in suitable locations.

- Location of firefighting, medical, and other emergency equipment

- o Evacuation procedures and location of evacuation routes. Routes should be posted in conspicuous and convenient locations.

- o Methods and responsibilities for firefighting, rescue, providing medical aid, and other special assignments. Fire brigades, when established by an employer, must comply with the requirements contained in 29 CFR 1910.156 [49]. Specific training in fighting grain fires should be included.

- o Methods and responsibilities for accounting for workers, visitors, or contractor personnel who may be in or immediately around the facility

A means of informing workers of an emergency should be an integral part of the emergency plan [36, 61, 63]. An employee alarm system must be provided, maintained, and tested in accordance with 29 CFR 1910.165 [49].

For the emergency plan to be effective it must be thoroughly understood by all affected personnel [36, 61, 63]. Training and instruction should be accomplished when a worker is initially hired and subsequently whenever the worker's actions or responsibilities change or procedures are modified. Retraining and/or drills should be conducted periodically to ensure that workers remain familiar with the procedures. Additional training is needed at least annually where personnel are assigned special duties such as firefighting and rescue or may be required to use emergency equipment. Training should be commensurate with the functions to be performed. Fire drills are recommended several times a year, depending on the size of the facility and the rate of employee turnover.

F. PERSONAL PROTECTIVE EQUIPMENT

Many cases have been recorded of traumatic injury, respiratory distress, and dermal exposure to toxic and corrosive substances in grain elevators and feed mills. A review of the literature indicates a significant number of injuries could have been prevented by the use of personal protective equipment. Engineering and administrative controls should be used where possible as the primary means of protection from workplace hazards. Use of personal protective equipment is necessary, however, where known controls are not fully effective or while controls are being implemented [51, 58, 64-66].

Although some types of personal protective equipment are needed in most facilities, specific requirements vary and should be determined by a qualified person on the basis of the facility, operations, location, and other considerations of the work environment. Major concerns which may necessitate the use of protective equipment in grain elevators and feed mills include the chance of falling objects, the presence of atmospheric dust, the use of fumigants, and the need to enter confined spaces. Other potential hazards which should be evaluated include exposure to high noise levels, overhead obstructions, temperature extremes, electrical equipment, sparks and flying objects, and irritating, corrosive, and toxic substances [58, 64, 65].

Protective equipment should be properly maintained and inspected on a regular basis. Visual inspections should normally be conducted before each use, and more thorough scheduled inspections accomplished depending upon the equipment. The type and frequency of required maintenance and inspection are usually available from the supplier or manufacturer or included in applicable

OSHA standards. Written records should be kept that reflect scheduled inspection dates, inspection results, and maintenance performed. Logs should also be kept on limited-life items.

The employer should be responsible for the provision of adequate protective equipment and its proper use by employees. This can more easily be accomplished if the workers understand the necessity for the equipment and if the equipment is not overly uncomfortable or cumbersome. Instruction and training are necessary to ensure that workers understand the limitations of the equipment and are able to use the equipment properly.

Items normally needed to protect personnel from injury or illness include hard hats, safety glasses or goggles, respirators, safety belts, harnesses, and lifelines. Other protective equipment such as ear plugs, protective footwear, gloves, and flotation devices may be required in some applications.

1. Head Protection

Protective headgear is needed where there is a possibility of impact from falling or flying objects or overhead obstructions. Specialized headgear may be required to protect against specific hazards such as electrical shock, burns, and exposure to cold weather. Headgear provided for protection from falling or flying objects must meet the requirements specified in 29 CFR 1910.135 [49]. Protective headgear should be visually inspected before each use and repaired or replaced when cracked, chipped, or otherwise damaged.

2. Eye and Face Protection

Suitable protection is needed where there is a chance of injury from flying objects or exposure to irritating substances. Impact-resistant safety glasses or safety goggles are required where there is a chance of injury from flying particles, sparks, or other small objects. Optically-corrected safety glasses or safety goggles that can be worn over optically-corrected glasses may be needed for persons using corrective lenses. Safety goggles may be required where eye-irritating chemicals, vapors, or dusts are present. A full coverage face shield is needed if both the eyes and face are exposed to a hazard. Protective eye and face equipment must meet the requirements in 29 CFR 1910.133 [49]. Persons engaged in welding and cutting operations must use goggles and shields in accordance with 29 CFR 1910.252 [49]. Contact lenses should not be worn in grain-handling or milling areas where airborne dust is present. Protective equipment should be visually inspected before each use for loose, scratched, pitted, or otherwise damaged components that may reduce protection or obscure vision.

3. Respiratory Protection

Appropriate respiratory protective equipment is needed whenever personnel are exposed to particulate, gas, or vapor contaminants exceeding the permissible exposure limits (PEL's), or an oxygen deficiency. The type of respiratory equipment used should be determined by a qualified person on the basis of the specific conditions and atmospheric test results. Respirators must be NIOSH/MSHA approved devices and be fitted, used, and maintained in accordance with 29 CFR 1910.134 [49].

Dust masks for protection from particulate contaminants are the most frequently used respiratory devices in grain-handling and grain-processing facilities. Dust masks may be disposable or have a reusable frame with a disposable filter element. Some facilities provide enclosed, forced air respiratory devices for excessively dusty operations such as bin cleaning. Chemical cartridge respirators are used to provide protection from low concentrations of known gases and vapors in areas where there is no oxygen deficiency. Supplied air respirators or self-contained breathing apparatuses are needed in oxygen-deficient atmospheres.

4. Fall Protection

Safety belts or harnesses are needed whenever employees are required to work at elevated stations 6 feet or more above grade level and are not otherwise protected from falls [67]. The belts or harnesses should be attached to a secure point or other device designed to prevent uncontrolled movement. Lanyards and lifelines should be sized or adjusted to minimize free-fall distance consistent with freedom of movement. On vehicles such as rail cars, where no reasonably effective secure point exists, other means of protecting workers, such as providing access platforms, should be considered. Belts or harnesses with lifelines are also needed when entering bins from above and in other applications where their use could prevent serious injury or enhance rescue.

Equipment should comply with the requirements contained in American National Standard A10.14, "Requirements for Safety Belts, Harnesses, Lanyards, Lifelines, and Drop Lines for Construction and Industrial Use" [68]. Prior to each use, equipment should be inspected for dry rot, chemical, mechanical, or other damage that may affect its strength. Defective lifelines should not be used. Care should be taken to ensure that the line is not placed over a sharp edge, or cut or pinched.

5. Hearing Protection

Ear plugs, ear muffs, or other suitable devices are needed when workers are exposed to ambient sound levels exceeding the permissible exposure levels specified in Table G-16 of 29 CFR 1910.95 [49]. Sound level meters used to measure noise levels must be compatible with the environment in which they are used. Rotation of personnel, restricting personnel access to noisy areas, use of barriers and other administrative and engineering controls should be used where possible to limit exposure.

6. Foot Protection

Personnel exposed to potential foot injuries as the result of impact from falling or rolling objects should be provided with protective footwear. Specialized footwear may be needed to protect against specific hazards such as electrical shock. Protective footwear must meet the specifications set forth in 29 CFR 1910.136 [49].

7. Hand Protection

Protective gloves may be required to protect workers exposed to sharp or abrasive surfaces or irritating chemicals. The type of glove needed is dependent upon the specific hazard. Impervious gloves should be worn when handling

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irritating chemicals. Other specialized gloves should be worn when hands are exposed to hazards such as electrical shock or thermal extremes.

8. Flotation Devices

U.S. Coast Guard approved personal flotation devices are needed whenever an employee is exposed to danger of falls into water, such as when working on barges and unprotected docks. At least one 30-inch U.S. Coast Guard approved life ring with not less than 90 feet of line attached is required on docks, in the vicinity of barges or vessels, and in other locations where employees work near water (29 CFR 1926.106) [69].

G. SAFE WORK PRACTICES

1. Dust Control

A comprehensive dust-control program is central to the control of fires and explosions in grain-handling and grain-processing facilities. Grain dust explosions can occur in enclosed areas whenever airborne dust concentrations are within certain limits and an ignition source is present. Good design and management can reduce the chance of a source of ignition being present. In practice, however, all potential sources of ignition cannot be completely eliminated. The exclusion of sources of ignition cannot be relied upon as the sole method of protection against explosion [2, 19, 25, 70].

Dust control can be achieved by various methods. For this reason, a requirement to use a specific method of dust control is not appropriate. Rather, a comprehensive dust-control program should be developed by a qualified person on the basis of the specific conditions at the facility. An effective dust-control program must address both airborne and layered dust. Although they may be considered separately, airborne and layered dust are complementary. Layered dust cannot be adequately controlled if airborne dust levels are excessive. Dust concentrations at grain transfer points and within handling and processing equipment should be maintained below the lower explosive limit. Airborne dust control should be such that, in conjunction with housekeeping activities, layered dust levels do not become excessive such that if made airborne the concentration would not exceed the lower explosive limit. In addition, when workers are present, exposure to airborne dust levels must be limited in accordance with the requirements contained in 29 CFR 1910.1000 [49].

Good housekeeping is probably the single most important factor in reducing the risks associated with secondary grain dust explosions. Even with effective airborne dust controls, some dust will escape and settle on floors, equipment, ledges, and other surfaces. Burning dust can cause a serious fire, or if disturbed, can initiate an explosion. In addition, dust accumulations can provide the fuel for extremely destructive secondary explosions. In many cases, a relatively minor primary explosion has been followed by a series of devastating secondary explosions fueled by layered dust thrown into suspension by the shock of previous explosions [19, 25, 53, 71, 72]. This layered dust need not be in open areas but may be hidden within bins and equipment. Although the value of good housekeeping should be recognized throughout the industry, there is no consensus of what constitutes a clean plant. Several sources, including the Canadian Grain Handling Association and Factory Mutual Research Corporation, recommend that layered dust levels should not exceed 1/8 inch, with the provision that every effort be made to do better [53, 71, 72].

Although the 1/8-inch limit, if maintained, would improve cleanliness levels in many facilities, it is considered excessive since dust accumulations as little as 1/64 inch could support secondary explosions if uniformly dispersed into the air [2, 21, 25, 73]. Because of the importance attributed to cleanup, it is recommended that thorough cleanup of floors, stairs, ledges, girders, machinery, spouting, and other surfaces within grain-handling and grain-processing areas where dust may accumulate be accomplished at least daily. The National Academy of Sciences [2] recommends, as a guideline, that layered dust in each gallery, tunnel, and workhouse not exceed 1/64 inch and if made airborne the concentration would not exceed 40 g/m^3 (0.04 oz/ft^3) for the total volume of the area. Grain spills would not be considered when using this guideline, only material that will pass through a 200-mesh screen (74 microns or smaller in diameter). Emphasis should be placed on cleanup of layered dust on motors, generators, bearings, and other heat-generating equipment and warm surfaces. In facilities where significant amounts of dust accumulate during a workday, daily cleanup may not be adequate, and additional dust cleanup should be provided, concurrent with operations [53]. When possible, dust should be cleaned up whenever visible tracks are recognized. The housekeeping program should address hidden, as well as visible dust. Layered dust within enclosures, and in other areas which are not easily accessible should be cleaned at regular intervals as determined by a qualified person. Daily housekeeping should be supplemented by periodic facility shutdown and thorough cleanup, including washing down where possible. These thorough cleanups should be accomplished at least yearly.

The method of dust cleanup should minimize generation of airborne dust. The most effective way to accomplish this is to use a central vacuum system. Portable vacuum systems can be used, but they are usually less efficient and can be difficult to maneuver around equipment. Vacuums should be acceptable for use in Class II, Group G, locations [74]. Vacuum cleaning systems are preferred for removal of static dust on surfaces in order to prevent resuspension of the dust in the air as is caused by brushing down with brooms or using compressed air ("blowing down") [2, 74]. If brooms are used for cleaning layered dust, they should be soft, and generation of excessive airborne dust should be avoided. If compressed air is used in facilities for "blowing down" surfaces and equipment which are not otherwise easily accessible, this must be done only after shutting down and isolating or locking out energy to equipment in the area and eliminating other possible ignition sources. Cleaning with compressed air should only be used to remove light films of dust where other means are not possible [75]. Sweeping dust from tops of equipment or ledges requires similar precautions if resulting airborne dust levels are within or near explosive limits.

Housekeeping considerations, such as minimizing horizontal ledges and blind or inaccessible areas, should be included in the facility design. Techniques such as the addition of sloped flashings to ledges can be used in existing facilities.

Airborne dust levels can be controlled by various techniques. Pneumatic dust-collection systems, when properly designed, maintained, and operated, effectively control dust levels at conveyor transfer points, distributors, cleaners, and other areas of turbulence [76]. Pneumatic systems use bag

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filters and cyclone separators, although cyclones are not being used in most new applications because they discharge some of the finer dust into the atmosphere. Cyclones are sometimes used in conjunction with bag filters to reduce the amount of dust collected in the filters. Although this can be effective, the setup is more complicated and less energy efficient. Removal of the larger particles in the cyclone may also contribute to clogging of the bag filters. Bag collectors and dust storage units should be vented or located outside the facility away from personnel to reduce their exposure to the explosion hazard.

Guidelines for the safe design, operation, and maintenance of pneumatic dust-collection systems are contained in the NAS report, "Pneumatic Dust Control in Grain Elevators: Guidelines for Design Operation and Maintenance, NMAB 367-3" [76]. Inspection, servicing, and maintenance of dust-control equipment should be accomplished on a regular basis. Handling and processing equipment should not be operated unless the associated dust-collection systems are also operating properly. Provisions for monitoring pressure at accessible locations in dust collectors are recommended to aid in verification of proper system operation. Pressure taps on branch ducts can be used to verify proper air velocity within the ducts.

Use of enclosed equipment, such as auger and drag conveyors, is effective in reducing airborne dust levels. In addition, enclosed belt conveyors are used in some facilities. However, enclosed equipment can pose a substantial explosion hazard if internal suspended dust levels exceed the lower explosive limit or if excessive dust deposits accumulate within the enclosure.

Ducts, spouts, and equipment casings should be dust tight. Access and inspection doors on bins, conveyors, bucket elevators, mixers, and other dust-producing equipment should be designed to be dust tight and should be kept closed when not in use. Other effective means of reducing airborne dust levels include speed reduction and the use of deeper troughs on belt conveyors, speed reduction and the use of larger capacity buckets on bucket elevators, the use of choke feeding at discharge points, the use of pressurization systems, the use of air aspiration systems, and the use of venting systems on scales, garners, and bins.

The hazards associated with returning collected dust to the grain are widely debated. Some individuals and organizations argue that limiting reintroduction of dust will not eliminate the explosion problem, since not all of the dust is removed from the grain and repeated handling generates additional dust [60, 77]. Other organizations recommend complete removal of all collected dust from the facility, a practice followed in grain elevators in Australia [75]. A strict dust control program, including the practice of not returning dust to the grain stream at any stage, and efforts in removing the possibility of ignition sources are thought to be the major reasons that Western Australia has not had a grain dust explosion over the past 50 years [78]. Their relative success compared to the United States may partly depend on the smaller number of facilities, the smaller volumes of grain handled, and the types of grain handled [1].

The U.S. Department of Agriculture believes that this single practice of not returning dust to the grain stream could significantly reduce the magnitude of the current explosion problem. Dust collected in bag filters usually contains a high percentage of very fine particles at reduced moisture content, which is easier to ignite and potentially more destructive. Since removal of this fine, artificially dried dust should alleviate the problems [1, 54, 60, 74], dust should not be reintroduced to the grain stream in grain elevators where it may be rehandled in the facility. Dust should never be reintroduced in areas of high turbulence, such as the boot pits of bucket elevators, where dust may be thrown into suspension.

2. Hot Work

Facility modifications and equipment repair frequently require welding and cutting in grain elevators and feed mills. These operations are potentially the most hazardous. Hot work has accounted for more fires and explosions in grain-handling facilities than any other known cause [1]. The extremely high temperatures and sparks generated during welding and cutting operations dictate the need for strict controls. Use of a permit system is one effective control measure [52, 60, 79-82]. Permits are needed for all hot work performed outside of designated maintenance areas to ensure necessary precautions have been taken. Hot work permits should be used for welding, cutting, brazing, soldering, grinding, using explosive-actuated tools, and any other operations which could produce high amounts of heat or energy.

The permit provides written authorization of a supervisor or other qualified person for performing the work. It is signed only after the work site has been inspected and it has been verified that the necessary precautions have been taken. The permit is also signed by the persons performing the work and by support personnel to indicate that they are aware of the potential hazards and safe work practices that should be followed. It is particularly important that contractors follow the permit requirements since they may not be familiar with the fire and explosion hazard in grain-handling and grain-processing facilities [19, 53, 60]. Prior to issuing a permit, the supervisor or qualified person should determine whether the work can reasonably be moved to a designated maintenance area or a nonhazardous area outside the facility. Alternate methods such as the use of hand saws or bolt fasteners may also minimize or eliminate the need for hot work. Although these alternate techniques are not always practical, they should be considered and evaluated prior to issuing the permit [53, 60, 79].

The expiration time for permits is not normally addressed in the literature. Some sources imply that a permit should be issued for each specific job. Others indicate that the permit should be renewed daily or at the beginning of each shift. Since a major intent of the permit is to verify that the operator is familiar with the hazards and the safety precautions, it is recommended that the permit be renewed at the beginning of each shift.

Personnel performing welding, cutting, or other hot work should be properly instructed and qualified to operate the equipment and be made aware of the hazards and associated safe work practices. Carelessness or lack of knowledge of the danger of dust explosions by the person performing the work has resulted in many explosions [82, 83]. Workers should receive training in proper use, maintenance and inspection of welding equipment, ventilation requirements, and requirements for protective equipment. Where work is accomplished in hazardous areas such as in confined spaces, in areas containing combustible materials, or on elevated work platforms, additional training is needed to cover the specific safe work practices. Outside contractors should be instructed on the specific fire and explosion hazards that they may encounter in grain-handling facilities.

Special precautions are necessary when there is an exposure to an area that has a hazard classification of Class II, Group G [3, 53, 60, 79, 81]. Complete shutdown of the facility prior to conducting any hot work in these areas is recommended. Where the entire facility cannot reasonably be shut down, dust-producing operations must be terminated within the work area and in adjacent areas where airborne dust could reach the work area. Necessary precautions, such as lockout techniques, must be taken to prevent inadvertent startup of equipment while it is being worked on or where airborne dust could be produced. Equipment should remain off until the hot work has been completed and cooled, the area has been inspected for residual heat and smoldering fires, and the equipment has been approved for restart.

Combustible materials within 35 feet of the work area must be removed (29 CFR 1910.252) [49]. When materials cannot reasonably be removed, they must be protected by fire-resistant shields or covers. Wetting of combustible materials in the area is recommended as an additional precaution. Care should be taken to protect combustibles such as plastic spout liners, leg belts, and cups which pose special problems since they may be concealed from view. Floors, ledges, and other surfaces within 35 feet of the hot work area must be thoroughly cleaned of dust and debris (29 CFR 1910.252) [49]. When hot work is elevated, the area under this, accounting for the wind draft of the slag and sparks, should be similarly cleaned. Cleanup should include removal of dust in overhead areas that could be disturbed during the hot work operation. Where hot work is performed on or near equipment or ducts, the interiors should be thoroughly cleaned or protected from high temperatures. Where hot work is performed near walls or floors, adjacent areas should also be inspected and cleaned. Wall, floor and other openings must be sealed where sparks or slag may reach.

A standby person with fire-extinguishing equipment is needed to monitor the area while the hot work is being performed and for at least 1/2 hour after cessation of the hot work. Additional checks up to 2 hours or more are recommended. A thorough inspection of the work area and adjacent areas should be made for residual heat and smoldering fires before the standby person leaves. If a security guard is employed during nonoperating hours, he or she should be advised that hot work has taken place.

Welding, cutting, and brazing equipment should be used in accordance with the manufacturers' instructions. Personnel must be provided with proper eye protection and other necessary protective equipment. Mechanical ventilation should be provided as necessary. Operations and equipment must comply with the requirements contained in 29 CFR 1910.252 [49].

3. Smoking, Open Flames, and Hot Surfaces

Flames are potent sources of ignition for dust suspensions [84]. Since flames can ignite dust suspensions and smoldering materials are easily converted into flames, it is universally agreed that smoking, smoking materials, or open flames should not be allowed in grain-handling, grain-storage, and grain-processing areas, or in immediately adjacent areas [23, 36, 60, 63, 85, 86].

Smoking may be permitted in areas specifically designated by management and isolated from ignition-susceptible areas, such as pressurized control rooms, which are free of dust and other flammables and combustibles. Although some sources recommend that smoking be completely banned within facilities, there is no evidence to indicate that smoking within dust-free areas designated by management presents a significant hazard. Smoking and nonsmoking areas should be clearly marked and smoking rules must be strictly enforced.

Heating equipment should be suitable for the location in which it is used. Other exposed surface temperatures of heated devices, including steam pipes, hot water pipes, and hot air ducts, should be kept below 71°C (160°F) [74].

4. Inspection and Maintenance

Workers in grain elevators and feed mills can receive injuries as a direct result of equipment failures. In addition, a significant number of dust fires and explosions in these facilities have been attributed to machinery malfunctions. A program of periodic surveillance and preventive maintenance is a necessary and effective means of keeping equipment and machinery functioning properly and reducing the number of unplanned failures [23, 55, 60, 63, 87-89].

A program of regular surveillance and preventive maintenance should be implemented at all plants to facilitate uninterrupted and safe operations. As a minimum, a program is needed for safety equipment, emergency equipment, and operational equipment where a malfunction could result in a direct injury or cause a fire, explosion, or other hazardous condition.

Inspection and maintenance requirements vary widely between facilities. Specific requirements should be established by a qualified person who is familiar with the facility, the equipment, and its use. Requirements should follow manufacturers' recommendations, although some modifications may be required depending upon the specific use environment of the equipment. All safety and emergency equipment such as fire extinguishers, hoses, standpipes, lifelines, and emergency ladders should be inspected periodically. Other equipment and components requiring periodic inspection and maintenance in grain elevators and feed mills include bucket elevators, grain dryers, grinders, dust-collection systems, conveyors, cleaners and scalpers, bearings, drive belts, manlifts and passenger elevators, powered vehicles, and electrical equipment. Inspection and maintenance should be performed at regularly scheduled intervals. Where normal nonoperating periods do not accommodate maintenance planning, scheduled periods of downtime should be allocated [52, 54, 55, 88, 89].

Recordkeeping requirements also vary between facilities. Written records are normally needed to ensure that necessary inspection and maintenance have been planned and are accomplished as scheduled. A list of equipment, including inspection and maintenance requirements, is needed to properly plan and implement a preventive maintenance program. Records maintained on the equipment should include the date, maintenance performed, and/or the results of the inspection. Records of equipment failures should also be maintained in order to identify possible deficiencies in inspection and maintenance planning. Many programs include work-order systems to provide a record of maintenance performed. Personnel should be instructed to report any abnormal equipment operations when detected; however, this practice should be used to supplement a maintenance program, not replace it [51, 55, 60, 63, 87-89]. Inspection and maintenance should be performed only by trained and authorized personnel.

5. Confined Spaces

Entry into confined spaces such as grain bins, hoppers, and other storage tanks is frequently required for cleaning, inspection or maintenance. The inherent dangers associated with confined spaces clearly indicate the need for strict control measures. According to the literature [42, 44, 45, 61, 90-93], the development of sound procedures, including the use of a permit system, is a very effective method of attaining control.

Procedures should be developed and implemented whenever workers are required to enter bins or other confined spaces. The procedures should include pre-entry preparation, entry, exit, work performed in the confined space, and emergency operations. Procedures for confined space entry may vary widely depending on the type and location of the confined space and the work to be performed. Procedures should be specifically designed for each type of entry.

The permit provides written authorization for entering and working in confined spaces, and clearly indicates the precautions which should be taken to ensure the safety of the worker. The permit should include the location and description of the work to be performed, hazards that may be encountered, results of atmospheric testing, precautionary measures, and safety and protective equipment required. The permit should be signed by a supervisor or other qualified person, the persons performing the work, and support personnel. Prior to signing the permit, it should be determined that the entry requirements have been met and necessary actions have been accomplished. Although permits may vary throughout the industry, they serve the same purpose; i.e., to ensure the safety of the worker.

One primary hazard associated with confined space entry is the possibility of atmospheric contaminants. Toxic contaminants may exist where pesticides or fumigants have been used. Composition changes in stored products may, over a period of time, reduce the oxygen content below safe levels or generate toxic materials. The need for atmospheric evaluation prior to confined space entry is reflected throughout the literature [42, 44, 45, 61, 90-93].

Confined spaces should be thoroughly ventilated prior to entry. Openings should remain open while the confined space is occupied to provide continuous ventilation. Forced air ventilation, where available, should continue when workers are in confined spaces, unless prevented by conditions such as excessive dust levels. Atmospheric testing is needed to ensure that the atmosphere is safe. Testing is needed to determine oxygen content, flammability, and presence of toxic materials [44]. If reduced oxygen levels or other harmful substances exist, additional ventilation may be provided to obtain acceptable levels. If safe levels cannot be obtained, entry should not be made unless appropriate respiratory protective equipment is worn.

Another major hazard associated with storage vessels is entrapment in flowing grain, which can lead to suffocation of personnel. Release of bridged materials or materials adhering to sides of containers has resulted in many fatalities. Some grains act like quicksand and a person can sink rapidly. The danger is much greater if the material is being drawn from the bottom of the bin. Confined spaces should be inspected for suspended materials prior to entry. Personnel should never work at levels below suspended material or while standing on materials which could break loose and bury them. Materials should not be fed into or drawn from bins which are occupied. Fill and discharge equipment, as well as equipment inside the confined space, should be isolated or locked out whenever inadvertent operation could create a hazard. Notification of personnel in control rooms and on all work levels that interface with the confined space should be included in the procedures [45, 61, 90, 94, 95]. Many fatalities in confined spaces can be directly attributed to a lack of communication with outside workers. Provisions for a standby person continuously monitoring workers in the confined space, and the use of proper protective equipment, including lifelines, provide further protection for the worker [44, 45, 61, 90-94]. The standby person and necessary rescue equipment should always be stationed outside the confined space when it is occupied. The standby person should have continuous communication capability with the workers in the confined space and be able to summon additional assistance if necessary. The standby person should not enter the confined space until adequate assistance is present and appropriate precautions are taken to prevent the rescuers from becoming disabled.

Necessary protective equipment, as determined by the qualified person, should be provided for workers in the confined space. Safety belts or harnesses with lanyards are needed in all applications where harmful atmospheres may exist. Safety harnesses are preferred. In many cases a safety belt would not properly support an individual in an upright position to permit removal of the individual from a typical silo or bin opening or other narrow opening. Respiratory equipment is needed where harmful atmospheres may exist. Air-supplied respiratory equipment is required if the oxygen level is below 19.5% [44]. Other protective equipment and clothing may also be needed. Hard hats are needed whenever there is a possibility of items falling into an occupied confined space.

Personnel who are required to work in a confined space or in support of those working in a confined space should be trained to recognize the hazards and know the safe work practices associated with entering, working in, and exiting that area. Personnel should receive training in normal and emergency entry and exit procedures; proper use of respirators, lifelines and harnesses, and other required protective equipment; isolation and lockout procedures; atmospheric testing requirements and procedures; purging and ventilating procedures; communications and emergency signals; and other safe work practices associated with the specific location, type and function of the confined space and the operation to be performed. Personnel who work in the vicinity of confined spaces should be aware of the associated hazards.

Equipment required to support operations in confined spaces, including boatswain's chairs, winches, protective equipment, and rescue equipment, should be inspected prior to use to ensure the equipment is in good condition. All equipment should be approved for the atmosphere in which it is to be used.

6. Isolation and Lockouts

Many accidents occur when energy is inadvertently applied to equipment that is being worked on. Energy isolation is needed during maintenance and repair activities to prevent worker injuries from unwanted startup of machinery, application of electrical energy to electrical lines or components, or other inadvertent application or release of energy. Accidents occurring under these circumstances frequently result in serious injury or death. Use of isolation and lockout procedures is a proven safety technique which should be used in all facilities to prevent injuries during maintenance, repair, servicing, inspection, cleaning, troubleshooting, and other similar activities [41, 51, 58, 61, 65, 96, 97]. Documented procedures ensure that the isolation technique is clearly defined and uniformly applied. Verification by a supervisor or other qualified person further ensures that the procedures are correctly applied and the isolation technique has been effective in isolating and/or dissipating hazardous energy.

For isolation procedures to be effective, energy should be isolated or blocked at a point or points of control that cannot be bypassed. The point of control should be secured by a device or technique which prevents unauthorized persons from reenergizing the equipment or machinery. Stored energy that constitutes a personnel hazard should be dissipated or blocked. Key-type padlocks are normally used in grain elevators and feed mills and are recommended for securing energy control points. Other techniques such as use of tags alone are successfully used in some industries; however, these techniques rely heavily on highly trained and experienced personnel, controlled access, and other procedural techniques not easily achievable in grain-handling and grain-processing facilities.

Key-type padlocks, when properly used, provide positive protection and can be applied in most cases where isolation is required. Padlocks should be fastened and removed only by the person performing the maintenance task. Keys should be issued only to the employee performing the task, and should be kept on his or her person at all times. When two or more employees are engaged in an operation that requires a lockout, each individual should have his or her own lock which has been installed in such a manner that the isolation device cannot be removed until each employee has removed his or her own lock.

Electrical isolation can be achieved by locking circuit breakers and/or main disconnects in the "OFF" position. Where more than one switch or disconnect supplies power to equipment, multiple padlocks are needed. Mechanical isolation of moving parts can be achieved by disconnecting linkages, removing drive belts, or using chains. It may be necessary to block or chain moving mechanical parts to prevent rotation, in addition to electrically isolating the equipment. Potential energy sources such as compressed springs and pneumatic and hydraulic pressure should be recognized and controlled by isolating, blocking, or otherwise neutralizing the energy. After the isolation procedure has been completed, an attempt should be made to operate the machinery or otherwise verify that the lockout device has been effectively applied. Any controls or switches operated during this verification should be returned to the "OFF" position.

Inspection, servicing, or troubleshooting should not be performed on operating equipment or machinery unless it can be determined that hazards are controlled with the energy present. Hazards should be evaluated by a qualified person and procedures should be developed which adequately control those hazards. Protective equipment and other special equipment needed should be included as part of this procedure.

All workers should receive general instruction on the equipment, operations, and types of energy isolation required at the facility. Specific lockout procedures, devices, and techniques should be addressed as applicable. Training should be sufficient to enable an employee to recognize the sources of energy which should be isolated, apply the isolation techniques properly, and recognize responsibilities with respect to equipment which has been isolated by other employees. Retraining should be accomplished as necessary to maintain proficiency and whenever procedures are modified.

7. Machine Guards

Machinery with rapidly moving external components are used in most grain elevators and feed mills. Unguarded nip points, shafts, sprockets, wheel drive mechanisms, and other moving parts are common hazards which have been responsible for many serious injuries. Many of the injuries would not have occurred if adequate guards had been provided. Requirements for guards vary widely and should be established by a qualified person on the basis of the specific configuration and location of the equipment in the facility. The exact configuration of the guard or barrier is not critical, as long as it covers or restricts access to moving parts in such a manner that they cannot be contacted [4, 51, 52, 54, 61, 65, 96].

Safeguards should be provided wherever there is a chance of personnel injury from contact with power transmission drives such as chain, belt, and rope drives; rotating shafts and sprockets such as those on bucket elevators, grinders, mixers, and trippers; nip points such as those occurring at the main pulleys on belt conveyors; and other rotating or translating machinery parts. Fixed or portable auger conveyors should never be operated without guards. Point of operation guarding should be provided for equipment such as sewing machines. Consideration should also be given to guarding heavily loaded lines and ropes such as those used in rail car pullers, where breakage could result in serious injury.

Complete enclosure of moving components is the preferred method of guarding, although guarding may be accomplished by the use of fences or barricades or by location of equipment in areas that are inaccessible to employees. When guarding by barricades or location is used, necessary precautions should be taken to prevent employees from entering areas where equipment is located. Guards designed and installed by equipment manufacturers are usually the most effective and should be specified where possible. When guards are built in-house, a major consideration should be ease of installation and removal. Guards should be removed only by trained and authorized personnel after necessary precautions such as equipment shutdown and lockout have been taken to minimize the chance of injury. Guards should comply with the requirements contained in 29 CFR 1910 Subpart O [49].

8. Labeling and Posting

Signs and labels are necessary to inform both workers and visitors of hazardous conditions in the workplace and precautions to be taken to prevent accidents. Although the use of accident prevention signs is infrequently mentioned in the literature, it is among the most widely used safety measures throughout industry [51]. Signs and/or labels should be provided whenever failure to recognize the condition could result in an unsafe action.

To be effective, signs should be concise, yet easily understood, and readily visible to persons entering or working in the area where the hazard exists. Persons unable to read or understand signs or labels should be informed of the hazardous condition reflected and associated instructions. When a significant number of workers read languages other than English, consideration should be given to printing signs both in English and the predominant language of the non-English-reading workers. Established symbols should be used whenever possible.

Signs needed in grain elevators and feed mills vary depending on the application. Recommendations should be established by a qualified person. Signs are normally used to designate (1) areas where specific practices such as smoking and hot work are prohibited, (2) areas where protective equipment is needed, (3) areas where combustible, flammable, and toxic materials are used or stored, (4) areas to which access is restricted, (5) special precautions or instructions needed for safe operation of vehicles, machinery, or equipment such as manlifts, (6) emergency evacuation routes and location of building exits (exits used only for emergencies should be designated), and (7) location of safety-related items such as first aid and fire fighting equipment.

Facilities should be inspected periodically to determine if signs or labels have been removed or have become illegible, or additional signs are necessary because of facility, equipment, or operational changes. Specifications for accident prevention signs and tags are contained in 29 CFR 1910.145 [49].

9. Other Safe Work Practices

a. Lightning Protection

Lightning has been reported as the probable cause for some dust explosions in grain-handling and grain-processing facilities [1]. Facilities in areas exposed to a substantial risk from lightning should have a lightning protection system. Guidelines for risk assessment and installation of lightning protection systems are contained in NFPA 78, "Lightning Protection Code" [98].

b. Foreign Material

Foreign objects such as tramp metal, stones and wood are frequently found in grain and feed stock. Introduction of these materials into the facility can produce sparks within the equipment. In addition, larger materials may jam between buckets and the casing in bucket elevators, causing sparks, frictional heating, or equipment damage that could contribute to an explosion. Allen and Calcote [99] reported that a shower of metal sparks of sufficient energy, such as might occur in continuous, high-speed grinding operations, could ignite an explosive dust cloud. It was not determined, however, whether sporadic or occasional sparking incidents would cause ignition. Although the degree of risk associated with sparks arising from impact is not fully defined, most sources recommend that precautionary measures be taken to remove foreign materials that may result in generation of sparks [23, 60, 62, 63, 72, 84, 100].

Several methods are commonly used to minimize the entry of foreign material into handling and processing equipment. In grain elevators, the main consideration is minimizing the amount of foreign material entering the grain-handling equipment, primarily bucket elevators, where most primary explosions in these facilities occur. Grates or screens are frequently used in receiving areas to remove materials that may be contained in the grain or feed. Although gratings do not remove all foreign materials, they are effective in removing larger materials regardless of composition. The spacing of a grating should be as small as possible consistent with the commodity being handled. Spacing of 1 1/2 inches is often recommended [100, 101]. Some facilities, however, require a spacing of 2 1/2 inches or more to accommodate special handling rates [102]. It is recommended that the receiving leg feeds be protected by a grate where the greater dimension is less than the cup projection and the lesser dimension is 1/2 the cup projection [2].

Magnets are used in many receiving areas to remove ferrous materials that may pass through the screens or grates. Although magnets do not always extract all ferrous materials entrained in the grain stream, medium and large-sized materials can be removed with high efficiency when magnets are properly selected, installed, and maintained. Although the best protection is achieved by the use of both gratings and magnets, magnets cannot be easily accommodated in many existing facilities and are not considered essential if other effective means of protecting against the entry of foreign materials are used.

In feed mills or grain elevators where equipment for grinding, pulverizing, and similar operations is used, additional precautions are needed [23, 63, 84, 85, 102]. Statistics indicate that hammer mills, roller mills, and other equipment where impact is part of the operation are second only to bucket elevators as the location of primary explosions [1]. Multiple magnets are used in some applications to remove ferrous materials, with feeding spouts arranged so that the materials pass over the magnets at low speeds. Pneumatic separators, gravity separators, and scalpers are also used upstream of grinders to effectively remove foreign materials. When screening-type devices are used, they should be designed to exclude from the processing machinery all foreign material (that may result in generation of sparks) larger than the grain being processed. Equipment used to collect or separate foreign materials should be kept in good repair and cleaned regularly.

c. Walking/Working Areas

Slips and falls traditionally have accounted for a high percentage of injuries in grain elevators and feed mills [17]. A significant number of the work injuries can be attributed to slippery or uneven footing. Good housekeeping and care of walking and working surfaces are necessary to reduce the number of injuries [4, 43, 103, 104]. Work areas should be kept free of debris which could cause slips, trips, falls, fires, or other accidents. Debris, such as lumber with protruding nails, should not be allowed to accumulate in receiving areas. Grain, grain dust, moisture, and ice can also cause serious accidents unless cleaned up or cleared as soon as possible.

Falls from heights usually result in more serious injuries than those that occur on the same level. These can normally be prevented by covering or guarding openings in floors, walls, and work platforms which are accessible to workers [61, 65]. Bins and other containers with floor openings should be kept covered when not being used. Where operational considerations such as the use of automated trippers dictate that bins be open continuously, other forms of protection and/or special procedures should be established for use by personnel required to work in those areas. Grating inserts are successfully used in many facilities to prevent falls into bins and distributor floor openings.

Floors, stairs, doors, ramps, and walkways should be kept in good repair and kept clear to provide unimpeded egress. At least two means of emergency escape should be provided from all general work areas normally occupied by personnel. Escape routes should be separated to the extent that a single event will not reasonably prevent access to all means of escape. Exits should be clearly marked. Other general requirements for means of egress are contained in 29 CFR 1910 Subpart E [49]. Specific recommendations for egress in grain elevators are contained in NFPA 101, "Code for Safety to Life from Fire in Buildings and Structures" [105].

d. Static Electricity

The magnitude of the hazard associated with static electricity in grain elevators and feed mills is not clearly defined. Although it is known that electrostatic charges are generated in the processing, transportation, and general handling of dusts, static electricity has never been proven to have caused a grain elevator explosion. One suspected case in a grain mill involved static discharges in a pneumatic conveying system. The statistical data are inconclusive, however, since the ignition source in over 40 percent of the reported explosions is unknown [1], and the presence of static electricity is difficult to trace following an explosion.

The extent of problems associated with electrostatic charges has been the subject of numerous investigations; however, valid predictions for practical applications have not been made. Dahn [106] found that although grain can accumulate moderate amounts of electrostatic charges when moving across spouts and chutes, such charges dissipate quickly when the grain comes into contact with a device or structure that is well grounded. It was also noted that if equipment is poorly grounded or isolated from ground, a potentially hazardous situation might quickly develop. The approach suggested by most professional sources is to assume that static charges will be generated; therefore, precautions should be taken to minimize the hazard [23, 60, 61, 63, 72, 84, 85]. Palmer [84] indicates that dusts with a minimum ignition energy of less than 25 millijoules should be regarded as prone to ignition by static electricity. This value is near the lower end of the ignition energy range usually attributed to grain dusts, suggesting that static electricity is a possible, but not a major source of ignition.

The primary areas of concern in grain-handling and grain-processing facilities are pneumatic conveyors and bucket elevators. Necessary precautions for these conveying systems include electrical bonding and grounding of frames and casings [23, 60, 61, 63, 72, 85]. Similar precautions are recommended on high speed continuous belt conveyors, although the problem is less significant if airborne dust levels are maintained below the lower explosive limit. Slow moving continuous belt systems such as those used for personnel transport (manlifts) or transport of bagged materials are not normally considered a problem. Use of electrically conductive belting is recommended by many sources; however, there is no agreement on the degree of conductivity. Studies have indicated that use of a conductive belt, in conjunction with a well grounded frame, safely dissipates static charges. Belts with the highest conductivity, however, can produce the highest spark discharge energy level in an ungrounded system [107]. For this reason, no specific recommendations are made relative to the use of electrically conductive conveyor belt material. When conductive belts are used, it is essential that a conductive path be provided from the belt to a well grounded frame. Usually, metal pulleys will pick up a charge from the belt and communicate that charge to the supporting shaft and through bearings to the equipment frame without special provisions. However, conditions such as the use of nonconductive lagging or bearing lubricants, or isolated frame sections may prevent components from being electrically common. Static collectors are also used in some facilities to remove electrostatic charges from conveyor systems. Guidelines for electrically bonding, grounding and using static collectors are contained in NFPA 77, "Recommended Practice on Static Electricity" [108].

e. Hazardous Materials Storage

Toxic materials, explosives, flammable and combustible fluids, and gases and other hazardous materials should be stored in suitable containers with their contents clearly identified. Hazardous materials should be stored outside the facility in detached buildings or approved tanks.

H. EQUIPMENT AND TOOLS

1. Bucket Elevators

Statistics indicate that bucket elevators are by far the most hazardous equipment, with respect to dust explosions, found in grain-handling and grain-processing facilities [1, 2].

More primary explosions have occurred in bucket elevators than in any other known location. Investigations have indicated that elevator legs routinely contain amounts of dust which exceed the lower explosive limit [2, 109]. Intense heat can be generated on the drive pulley in the event of belt stalling. Belts may burn through and drop into the leg, resulting in ignition of dust from burning fragments or from sparks generated by metal components striking the casing [23, 60, 109, 110].

Bucket elevators should be located outside the facility where possible. In bucket elevators, belt speed monitoring devices are needed to detect belt and pulley slowdown and to allow corrective action to be taken before frictional heating ignites the belt or grain [60, 61, 102, 109-111]. When the bucket elevator speed drops below a predetermined value, the slowdown detection device should activate an alarm, initiate stoppage of the supply of material to the bucket elevator, and cut off power to the elevator drive motor. The best method of detecting slippage is to monitor the drive and tail pulleys for variations in the speed ratio. Since operating speed is nearly constant in most cases, simple devices which monitor belt and pulley speed are usually adequate. Manual shutdown can be accomplished or it can be done automatically by sending a signal to a device which turns off power to the drive motors. To prevent unnecessary shutdowns, a 30-second time delay may be incorporated into the system to allow the bucket elevator to attempt to clear after the supply of material to the elevator has been stopped. If shutdown is to be accomplished manually, procedural controls should be established to ensure that corrective action is taken in a timely manner. Necessary procedural controls include having a worker continuously stationed in the vicinity of the elevator controls and in a location where the alarm can be detected at all times. The worker should be instructed to shut down the bucket elevator immediately or after a short time delay to give the equipment a chance to clear.

The exact setting of the slowdown detection device is dependent on the specific application. Typically, speed reductions from 5% to 20% of normal operating speed indicate a significant problem [71, 109, 112]. For most applications, a setting of 5% to 10% of normal operating speed is adequate to detect malfunctions without causing accidental tripping during normal operations. The slowdown detection device should be fail-safe (i.e., sound an alarm or initiate equipment shutdown if the device malfunctions) or be checked regularly to verify proper operation.

Ammeters and dual level monitoring devices may also be used to give an indication of slowdown before the cutoff speed is reached. Use of ammeters alone, however, does not provide a positive method of detecting belt slippage because the meters are not always monitored and slippage is not always a direct function of motor current. Reliance upon thermal cutoffs on drive motors to shut down elevators in the event of belt slowdown is not considered acceptable because of possible long delay times before thermal limits are exceeded or motors that may continue to drive the head pulley without overheating [109].

If a choked leg does occur, the problem should be identified and corrected prior to restarting the motor. Written procedures should be developed by a qualified person and implemented for safe shutdown, clearing, and startup. Jogging drive motors may result in belt slippage and should never be attempted [61, 110]. Thermal protection on drive motors should not be bypassed. In addition to checking and clearing the boot pit, the belt, buckets, and head need to be inspected to see if they are clear. Equipment should be checked for damage after it is cleared and repaired if necessary. Belt movement should be monitored during startup. Power to the drive motor should be cut off if the belt does not move or if slippage occurs. After restarting, equipment should be monitored for unusual noises, excessive motor loading, or other abnormal operating conditions.

Other potential ignition sources associated with bucket elevators, including overheated bearings, pulleys or belts rubbing on frame or casing, and metallic buckets striking the frame or casing, dictate the need for regular inspection and maintenance [60, 102, 109, 110]. Bearings should be located on the outside of the leg casing. Periodic inspection is needed for proper alignment, tension, and tracking of belts; loose or damaged buckets; adequate clearances between belts/buckets and casings; excessive wear on belt or lagging; defective belt splices; worn or defective bearings; and loose or slipping drive mechanisms. Inspections should be conducted at least once during each shift in which the equipment is operated. Adequate inspection and clean-out doors are needed to support this operation. Only trained and authorized personnel should service or operate equipment. In addition to scheduled inspection, workers should be instructed to report any unusual equipment noise or defective equipment whenever it is observed. Instrumentation such as plug or level sensors, bearing temperature sensors, belt alignment sensors, and vibration sensors should be used to assist in early detection of equipment malfunctions [2].

Exterior bucket elevators should be provided with explosion venting to the outside atmosphere. Although venting does not prevent explosions, it does reduce the pressure buildup and helps to limit the amount of destruction [23]. Research conducted by Gillis [113] indicates that explosion venting can be used effectively to protect bucket elevators from explosions. Explosion venting on new bucket elevators should be accommodated in the initial design. Venting of existing bucket elevators is not always feasible; however, it can be provided in many applications. In the case of interior bucket elevators that extend through the headhouse roof, venting may be provided at the head of the elevator. Although not fully effective, this particular vent would provide relief for explosions occurring in the proximity of the elevator head. Guidelines for explosion venting techniques are included in NFPA 68, "Guide for Explosion Venting" [114].

2. Grain Dryers

Dryers are used in many grain elevators to reduce moisture to levels low enough to preserve quality. A relatively small number of explosions have occurred in dryers; however, they are one of the most frequent causes of fires [1, 23]. Because of the heat generated by dryers and the high chance of fires, location of dryers is of primary importance. Dryers should be located or isolated to minimize ignition potential to handling and storage areas and adjacent structures. Locating dryers away from the storage unit is one method of minimizing the risk of serious fires and explosions in the storage areas [23].

Necessary precautions should be taken to minimize the chance of ignition of grain within the dryer and, if a fire occurs, to prevent burning materials from entering storage or processing areas. Instrumentation is needed to detect excessive air stream temperatures at the inlet and outlet of the drying chamber and excessive product temperatures at the product discharge. Detection of excessive temperatures should result in automatic shutdown of the dryer, stoppage of the product flow and activation of an alarm at a constantly attended location. Even when equipment is working normally, operation should be continuously monitored by personnel.

Grain dryers are normally provided with adequate safety devices by the manufacturer; however, exposure to weather, moist grain, and temperature extremes eventually cause malfunctions. Thorough cleaning, inspection, and testing on a regular basis are necessary to maintain proper operation. Operation and maintenance should be conducted only by trained and authorized personnel. Personnel operating dryers should be thoroughly familiar with equipment controls, gauges, and safety devices. Training should include detection of abnormal operating conditions and safety and contingency procedures. Maintenance personnel should be instructed in inspection, cleaning, maintenance, and repair procedures. Proper operating and maintenance techniques should be obtained from the equipment manufacturer or supplier.

Additional guidelines for the design and safe operation of grain dryers, including provisions for rapidly unloading the dryer contents, using temperature limit controls and alarms, monitoring operation, instructing operators on safe operation of the dryer, and periodically inspecting and performing maintenance are included in NFPA 61B, "Standard for the Prevention of Fires and Explosions in Grain Elevators and Facilities Handling Bulk Raw Agricultural Commodities" [74].

3. Electrical Equipment

The need for controls on the use of electrical equipment in grain elevators and feed mills is reflected throughout the literature [23, 53, 60, 63, 84, 87, 100, 102]. In addition to the electrical shock hazard, sparks or heat produced during the normal working of switches, contact breakers, commutator motors, and other electrical equipment can ignite dusts. Energy available in electrical equipment is usually greatly in excess of the amount of energy required to ignite common grain dusts [23, 53, 84].

Safeguards from hazards associated with the use of electricity are included in 29 CFR 1910 Subpart S [49]. Maintenance of equipment should be in accordance with manufacturers' recommendations. In areas designated as Class II, Divisions 1 and 2, which are hazardous because of the presence of combustible dust, special precautions are required. In general, equipment, and methods of wiring and installing equipment in Class II, Divisions 1 and 2 locations in grain elevators and feed mills should be (1) approved as intrinsically safe for that area, (2) approved for that location and atmospheric Group G, or (3) of a type and design which the employer demonstrates will provide protection from the hazards arising from the presence of combustible grain dust. The NFPA 70, "National Electrical Code" (Articles 500 and 502) contains design, installation, and maintenance guidelines for "dust-ignition-proof" equipment which is safe for use in Class II, Divisions 1 and 2 locations [50]. Equipment should be enclosed to prevent entry of dust which could ignite or affect performance. In addition, sparks or heat generated inside the equipment cannot cause ignition of external layered or atmospheric dust. For equipment that is not subject to overloading, maximum surface temperature in this class is 165°C (329°F). For equipment such as motors or power transformers that may be overloaded, maximum surface temperature during normal operation is 120°C (248°F); maximum surface temperature during abnormal operation is 165°C (329°). "Explosion-proof" equipment may not be acceptable for use in grain-handling and grain-processing areas and should not be used unless specifically approved for Class II locations. Equipment approved for Class II, Division 1 locations can be safely used in Class II, Division 2 locations.

When possible, electrical equipment should be placed in non-Class II locations such as building areas other than those used for grain storage and processing, separate buildings adjacent to the storage and processing areas, or enclosures supplied with positive pressure ventilation from a source of clean air. When pressurized enclosures are used to obtain classification as a nonhazardous location, positive means should be provided to detect malfunctions of the pressurization equipment. Guidelines for the design of pressurized enclosures are contained in NFPA 496, "Standard for Purged and Pressurized Enclosures for Electrical Equipment in Hazardous (Classified) Locations" [115].

In addition to compliance with 29 CFR 1910 Subpart S [49], special precautions should be taken when using portable lighting inside of equipment. When portable lighting must be lowered into bins, pits, bucket elevators, or other equipment or enclosures containing dust, care should be taken to prevent damage to the light or cord. Lighting should not be supported by the electrical cord unless so designed for that purpose. The light should not be dropped or struck on walls or casings. Several explosions have occurred because of damage to portable lights lowered into equipment while it was operating [1, 83]. Equipment such as bucket elevators should not be operated while lights are inside so as to prevent entanglement and shorting of the light or cord. Lights should not be lowered into bins when materials are being withdrawn in order to prevent the light from being drawn into the material and becoming damaged. If portable lights do become entangled or caught, they should be disconnected from the power source before any force is applied which could damage the light or cord.

4. Manlifts

Manlifts are used in many facilities to provide access to the various work levels. Faulty equipment, lack of safety devices, and improper use of manlifts can cause serious injury. Workers should be instructed in the proper use of manlifts to ensure that they are familiar with the precautions that should be taken for safe operation [4, 58, 61, 116].

Manlifts should be used for conveyance of personnel only. Transportation of freight, packaged goods, sacks, and other materials on manlifts should be avoided since it may prevent the operator from using the manlift safely. In addition, materials being transported may fall and injure personnel on lower levels. Employers are responsible for ensuring that manlifts are not used for freight; however, enforcement can be difficult unless other convenient means are provided to transfer materials between levels. Signs informing employees of restrictions on conveyance of materials may be effective. Carrying of hand tools should also be avoided on manlifts unless the tools can be adequately secured in pockets or tool belts. Bulky tool belts which significantly reduce clearances should be avoided.

Guards should be provided to prevent inadvertent contact with moving parts and access to floor openings by personnel other than those using the manlift. Other specific requirements for the construction, maintenance, inspection, and operation of manlifts are contained in 29 CFR 1910.68 [49]. Manlifts should be used only by persons authorized by the employer and trained in their use. Instruction should include proper techniques for entering, riding, exiting, starting, and stopping manlifts. Emphasis should be made to employees against transporting equipment and unsecured or protruding tools on manlifts. A demonstration of proper operating techniques should be given at the manlift site and, following instruction, employees should use the manlift while being monitored by the instructor.

5. Hand and Portable Power Tools

Proper selection and use of hand and portable power tools are necessary in any industry to minimize worker injuries. It is important to use tools properly, keep them in good repair, and perform periodic inspection and maintenance [51, 52, 58, 117].

Tools should be kept in good condition and repaired or discarded when defective. Most defects can be detected visually by the user. Impact tools with mushroomed heads, hammers with faulty handles or loose heads, and wrenches with sprung jaws should be repaired or discarded. Periodic verification of the grounding system is necessary on electrical equipment, as well as inspection of cords and plugs for defective insulation or other damage. Employers and employees share the responsibility for the safe condition of tools. Regular inspection and maintenance should be performed to ensure tools are kept in good repair. Workers should be instructed in the proper selection and operation of tools they will be using, including any protective equipment that is required.

Portable power tools, when used, must comply with the requirements contained in 29 CFR 1910.243 [49]. Portable electrical tools must be in accordance with 29 CFR 1910 Subpart S [49]: i.e., be equipped with a grounding conductor terminating in ground fault circuit interrupters or a grounding-type attachment plug, be protected by an approved double-insulation system, or be used in circuits provided with ground fault circuit interrupters. Tool grounding system continuity should be verified at least quarterly. Checks should be made more often if equipment is subjected to heavy usage. Electrical tools with defective grounding systems, insulation, or plugs should not be used. Electrical tools should not be used in Class II locations unless dust in the work area has been cleaned up thoroughly and dust-producing equipment in the vicinity has been shut down.

Pneumatically-powered equipment is frequently used in Class II locations to reduce the risks associated with the use of ordinary electrical tools. Pneumatic equipment can be used safely; however, precautions should still be taken to minimize airborne and layered dust in the work area since local heating or sparks may be generated by drill bits, grinding wheels, or other attachments [45]. When pneumatic power is used, care should be taken to ensure that the tools and associated hoses and fittings are compatible with the pressure at which they are being used.

Nonsparking shovels and other hand tools are used in some grain-handling and grain-processing facilities, although statistics indicate the degree of risk associated with ordinary tools is low. Cross [118] reported that available accident data are not statistically significant for completely addressing metal sparks as an ignition source. She found that high friction and continuous sparking incidents could be an ignition source in some cases, but that additional research is needed before a determination is made of whether sporadic or occasional sparking incidents involving malfunctioning equipment and foreign material are a hazard. The use of nonsparking tools in confined, dusty locations is recommended by some sources [45, 90, 91] as a precautionary measure. A blanket recommendation for nonsparking tools cannot be justified.

6. Industrial Trucks

Design, maintenance, and use of fork trucks, tractors, lift trucks, motorized hand trucks, and other powered industrial trucks must comply with the requirements of 29 CFR 1910.178 [49]. Powered trucks used in Class II, Group G locations must be designated for use in these locations and be labeled or marked to indicate the approval of a recognized testing laboratory.

Powered industrial trucks are frequently used in and around grain elevators and feed mills for unloading bulk materials from flat storage bins, rail cars and barges, and for other material-handling and utility purposes. Regardless of application, powered industrial trucks should contain appropriate safeguards for both the operator and other personnel. Procedures for safe operation, inspection, and maintenance should be established. Trucks should always be operated within their design capacities and perform only those operations for which they are intended. Overloading and operating at excessive speeds should be avoided. Special care is needed when operating on slippery, uneven, or sloped surfaces. Fueling should be accomplished only in designated areas. Adequate ventilation must be provided whenever powered industrial trucks are used within buildings and other enclosures. Only properly trained and authorized personnel should operate or service industrial trucks [51, 119-121].

Training for operators of industrial trucks should include classroom instruction, demonstrations, and practice sessions. Instruction should include identification and operation of controls and gauges, loaded and unloaded maneuvering techniques, material-handling techniques, and other safe operating practices. Operating manuals and other training guidelines should be obtained from manufacturers or suppliers and used to develop training programs. Following training, personnel should demonstrate the ability to operate vehicles to the satisfaction of the instructor.

7. Ladders and Scaffolds

Ladders and scaffolds are frequently used for maintenance and repair operations in grain-handling and grain-processing facilities. Ladders are also commonly used for normal access between work levels and emergency escape routes. Accidents may be caused by climbing or descending improperly, over-reaching, and failing to secure movable equipment. Falls from ladders and scaffolds frequently result in serious injuries. Instruction in the proper use of ladders and scaffolds is necessary to ensure that workers are familiar with the precautions which should be taken to prevent accidents [37, 51, 58, 122].

Portable ladders should be structurally sound, adequately secured, and properly sized for a specific task. Both tops and bottoms should be positioned against solid objects and, where necessary, held, tied, or otherwise securely anchored to prevent slipping. Additional precautions are needed if the ladder is positioned where it could be struck by vehicles, doors, or other moving objects. Metal ladders should not be used where there is a possibility of contacting live electrical parts. Ladders should be inspected for loose, cracked, or otherwise defective parts prior to use. Defective ladders should be conspicuously marked, repaired expeditiously, or removed to prevent inadvertent use. Portable ladders must meet the care and use requirements contained in 29 CFR 1910.25 and .26 [49].

Devices designed to prevent uncontrolled falls are needed for fixed ladders over 20 feet (6 m) in unbroken length (29 CFR 1910.27) [49]. Cage guards are most commonly used, although safety devices which incorporate safety belts and friction brakes or sliding attachments are also used. Friction brakes and sliding attachments can provide more positive protection than cage guards; however, specialized training is needed for their use. Safety devices should not restrict use of ladders by persons with rescue or other emergency equipment. Fall-protection devices are not considered mandatory by OSHA on ladders used exclusively as a means of egress from fires and like emergencies. Fixed ladders should be inspected regularly for loose, worn, or damaged parts and comply with the requirements in 29 CFR 1910.27 [49]. Inspection is especially important for emergency ladders where defects may not be noticed during normal operations.

Scaffolds must be designed to support at least four times the maximum load and be adequately secured when in use (29 CFR 1910.28) [49]. Guardrails or other safety devices are required where workers are exposed to falls of 10 feet (3 m) or more (29 CFR 1910.28) [49]. Safety belts or harnesses in conjunction with lifelines are needed for workers on suspended scaffolds or platforms. Lifelines should be attached to a secure point other than the scaffold. Scaffold decking should be secure and provide adequate traction. Scaffolds must be inspected for defects by a competent person at least daily when in use and must meet the requirements contained in 29 CFR 1910.28 [49].

8. Compressed Gas Equipment

Compressed gas is frequently used for cleaning, powering pneumatic tools, and for other applications in grain-handling and grain-processing facilities. Improper use of compressed air can be highly dangerous. Compressed air jets directed toward a worker's body or clothing can drive particles into the skin, break eardrums, or cause other serious injuries [39, 51, 58]. Respiratory and eye protective equipment should always be provided to prevent particles from entering the worker's eyes or mouth when using compressed air for cleanup.

Equipment in the area should be shut down and other potential ignition sources eliminated before dislodging dust.

Caution should also be exercised when using compressed gas cylinders. Cylinders should be clearly marked or color coded to identify the contents. Cylinders should be protected from damage during storage and handling. Cylinders should be stored where they are not exposed to excessive heat or moisture, and flammable gases should be stored away from main buildings. Cylinder valves should be turned off when not in use and valve protection caps should be in place. Cylinders and compressed air receivers must have relief devices installed and meet the requirements contained in 29 CFR 1910 Subpart M [49]. Cylinders used in welding, cutting, or brazing must meet the additional requirements contained in 29 CFR 1910.252 [49]. Only trained and authorized persons should interface with compressed gas equipment.

9. Hoisting Equipment

Hoists and other lifting devices are frequently used for transporting heavy equipment and machinery. Hoists are also used for lowering personnel into bins for cleaning and inspection. To prevent accidents, loads should be secure and stable and equipment should be inspected and maintained in accordance with manufacturers' recommendations. Equipment should only be used by personnel thoroughly instructed and trained in its use [51, 58].

Equipment must be used within its rated capacity [49]. All equipment, including slings, cables, ropes, hooks, and other attachments should be visually inspected for defects prior to use. Also, brakes should be tested before lifting. Loads should be adequately secured and balanced to prevent materials from becoming disengaged. Operators should verify that all personnel are clear of the lifting area prior to raising a load.

Design and use of hoists, cranes, derricks, and slings used to elevate equipment must comply with the requirements of 29 CFR 1910.179, .181, and .184 [49]. Hoists should not be used to transport personnel unless a working platform designed for that purpose is provided.

Additional precautions are needed when using boatswain's chairs suspended from hoists. When portable equipment is used, the footing should be secure. The boatswain's chair should be attached by four legs to obtain stability in a manner which ensures positive engagement. Safety belts or harnesses with lifelines should be provided for personnel using boatswain's chairs.

All hoisting operations should be conducted by trained personnel. Experienced persons should be designated to supervise the operations. Operator training should include instruction in proper use of the equipment including use of brakes and other safety features. Operators should also be trained to recognize defective or excessively worn parts. Additional training should be provided when personnel may operate hoisting equipment for the purpose of lowering workers into bins. Methods of properly securing and balancing loads should be emphasized. Following instruction and training, operators should demonstrate their ability to use the equipment to the satisfaction of the instructor. Periodic retraining should be accomplished.

I. FIRE PROTECTION

1. Portable Fire Extinguishers

Portable fire extinguishers in a fully charged and operable condition must be provided throughout all buildings, unless employees are specifically instructed not to fight fires and to evacuate the facility if a fire occurs (29 CFR 1910.157(b)) [49]. Portable fire extinguishers provided for employee use must meet the requirements defined in 29 CFR 1910.157 [49] to ensure that the extinguishers are readily available and in good operating condition. Training is essential for employees required to use extinguishers and other fire fighting equipment since improper use can create additional hazards. Instruction should include the proper type of extinguishers to use on the different classes of fire and the proper technique to extinguish fires. Foam extinguishers are sometimes recommended to minimize dispersal of dust when fighting fires.

2. Standpipes and Hoses

Wet or dry standpipes and hoses should be installed in all areas located more than 75 feet above ground level in which combustible materials other than grain are stored [72, 74]. Dry standpipes are usually recommended to prevent freezing in cold weather and loss of facility water supplies if pipes rupture in an explosion. Standpipes should be provide with 1 1/2-inch hose lines and combination fog/straight stream nozzles. Where standpipes are provided, they must meet the requirements in 29 CFR 1910.158. [49]

3. Automatic Sprinklers

Automatic sprinkler systems are recommended in areas containing combustible construction or equipment [53, 72]. Where sprinkler systems are provided, they must meet the requirements in 29 CFR 1910.159 [49].

4. Hydrants

Either public or private hydrants should be provided for fire fighting use. Hydrants should be supplied by an adequate water supply [74].

5. Explosion Suppression

Explosion suppression systems are available for use in areas such as bins, distributors, tanks, dust collectors, etc. The use of these systems should be considered in unusually hazardous areas (e.g. elevator legs), in dust collection systems, and in locations where other means of control are not necessarily suitable [74]. Where explosion suppression systems are provided, they must meet the requirements in 29 CFR 1910.160 and .162 [49].

6. Fire Fighting Operations

Initially, the contents and the extent of the fire should be determined. If the fire involves equipment, the general procedure should be to shut down the equipment, isolate the fire if possible, extinguish and remove any burning material, and inspect for damage before restarting the equipment.

With dust fires, it is of critical importance to avoid extinguishing methods which spread or disperse the dusts into suspension. The use of water from a hose under high pressure may throw large quantities of dust into suspension and raise an extreme risk of explosion. Fire fighters should exercise caution in fighting grain dust fires. Some sources recommend the use of water applied as low pressure fog or fine mist although one case is known where this resulted in the dispersal of burning dust and a subsequent explosion. Until better extinguishing methods are developed, and where it can be done safely, it may be better to carefully remove burning grain and dust from the grain facility by using buckets and shovels and then complete the extinguishment of the burning grain outside the facility [2, 74, 123-126].

J. FIRST AID

Prompt first aid treatment following an injury may prevent the condition from becoming more severe. Medical personnel, or someone currently trained in basic first aid procedures, and an adequate supply of first aid equipment should be readily available to all workers. Workers should be made aware of how to obtain emergency medical attention.

Facilities for drenching or flushing the eyes are needed in the immediate area wherever there is a chance of corrosive or otherwise harmful chemicals being splashed into the eyes (29 CFR 1910.151) [49]. A shower should be provided whenever there is a chance of corrosive or otherwise harmful chemicals contacting a large portion of the body. Stretchers for transporting injured workers should also be available in the facility or through nearby fire departments or other emergency organizations. Basket stretchers should be available where injured workers may have to be lifted or lowered from areas which are not easily accessible.