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Lesson Summary

To understand accident causation, investigations rely on the idea that most accidents are caused by human error. Therefore, if you learn the cause-and-effect relationship of accident causation and the human element, then you can reduce injuries and illnesses. Though there are additional factors to consider, the human element is a leading cause of accidents.

Theories of accident causation include:

- Single factor theory, which traces the cause of an accident back to a single factor. This is unrealistic and the single factor theory is rarely used.
- H.W. Heinrich's domino theory, which analyzes an accident as a chain of three phases: pre-contact, contact, and post-contact. According to Heinrich, by removing one of the "dominos" in this sequence, accidents and their negative effects can be prevented.
- The multiple factor theory holds that there are more than Heinrich's three phases to consider when investigating an accident – that there are multiple factors that contribute to the cause.
- The human factor theory traces all accidents back to human error.
- James Reason's Swiss cheese theory uses the holes in slices of Swiss cheese to explain accident causation. The holes represent breakdowns in safety, and when enough holes line up an accident can occur.

Commonly used accident investigation techniques include root cause analysis and the 5 Whys. A root cause analysis is a detailed procedure used by safety professionals to look beyond the initial reactions, which may be informed more by emotion than careful thought, to assign blame for an incident.

A behavior-based safety (BBS) program picks at-risk behaviors and monitors workers to understand why they behave in those ways. Some common human performance snares include time constraints, distractions, multitasking, overconfidence, vague guidance, and peer pressure.

Module 3: OSHA Focus Four Hazards

Module Description

Construction safety is one of OSHA's top concerns. Construction is among the most dangerous industries in the country and construction inspections comprise 60% of OSHA's total inspections. In 2019, preliminary data from the Bureau of Labor Statistics indicate that there were 1,061 fatal on-the-job injuries to construction workers – more than in any other single industry sector and nearly one out of every five work-related deaths in the U.S. that year. Also, in 2018, private industry construction workers had a fatal occupational injury rate nearly three times that of all workers in the United States.

The Construction Focus Four Module was developed in support of the Occupational Safety and Health Administration (OSHA) Construction Outreach Program's effort to help workers in the construction industry understand the hazards they face and know what their employer's responsibilities are regarding protecting workers from workplace hazards.

OSHA's Construction Focus Four hazards include 1) falls, 2) caught-in or caught-between injuries, 3) struck-by injuries, and 4) electrocution. The OSHA standards covered here identify various construction worksite areas and activities that can lead to these hazards. In this module, you will learn about the duties of the employers, the importance of identifying and evaluating focus four hazards, and the necessity of providing training to employees.

Module Learning Objectives

At the end of this module, students will be able to:

- Identify the focus four hazards
- Describe various types of hazards that fall into the focus four categories
- Explain how workers can protect themselves from the focus four hazards
- Recognize employer requirements to protect workers from these hazards

Lesson 1: Fall Protection

Lesson Focus

At the end of this lesson, students will be able to:

- Describe the causes and dangers of falls
- Identify the types of work requiring fall protection
- Understand how passive fall protection systems work
- Understand how active fall protection systems work
- Explain how to provide protection from falling objects

Falls and Fall Protection

Falls are the leading cause of fatalities in the construction industry. In 2019, 401 out of a total of 1,102 construction fatalities were the result of falls (NIOSH). Data from a long-term study indicates the types of falls that are causing worker deaths. In the period 1992-2005, about one-third of the fatal falls in construction were from roofs, 18% were from scaffolding or staging, 16% were from ladders, and 8% were from girders or structural steel. The other 25% of fatal falls includes falls through existing floor openings, from nonmoving vehicles, from aerial lifts, etc.

The Physics of a Fall

A body in motion can cover vast distances in a short period of time. Consider this:

- A body in free fall can travel 4 feet in 0.5 seconds
- A body in free fall can travel 16 feet in 1 second
- A body in free fall can travel 64 feet in 2 seconds
- A body in free fall can travel 144 feet in just 3 seconds

Because gravity causes us to fall at accelerating speeds, it only takes a few seconds for a falling body to cover a great distance and impact the ground or another surface with a great deal of force. Such force can easily cause injuries or death.

Fall Prevention Measures

In order to prevent workers from falling, employers must:

- Select fall protection systems appropriate for given situations
- Use proper construction and installation of safety systems
- Supervise employees properly
- Use safe work procedures
- Train workers in the proper selection, use, and maintenance of fall protection systems

Areas Required to Have Fall Protection

Depending on the circumstances, the following areas are required to have fall protection:

- Unprotected sides and edges
- Leading edges
- Hoist areas
- Holes
- Formwork and reinforcing steel
- Ramps, runways, and other walkways
- Excavations
- Dangerous equipment
- Overhand bricklaying and related work
- Roofing work on low-slope roofs
- Roofs
- Pre-cast concrete erection
- Residential construction
- Wall openings
- Walking/working surfaces not otherwise addressed

Duty to Have Fall Protection

Fall protection is generally required when one or more employees have exposure to falls of six feet or greater to a lower level.

Surfaces must be inspected before the work begins. Employees are only permitted to be on surfaces that are strong enough to support them. Employers are required to assess the workplace to determine if the walking/working surfaces on which employees are to work have the strength and structural integrity to safely support workers. Employees are not permitted to work on those surfaces until it has been determined that the surfaces have the requisite strength and structural integrity to support workers. Once employers have determined that the surface is safe for employees to work on, the employer must select one of the available options for the work operation if a fall hazard is present.

Types of Work Requiring Fall Protection

Leading Edge Work

The leading-edge means the unprotected side and edge of a floor, roof, or formwork for a floor or other walking/working surface (such as a deck) which changes location as additional floor, roof, decking, or formwork sections are placed, formed, or constructed.

Almost all sites have unprotected sides and edges, wall openings, or floor holes at some point during construction. If these sides and openings are not protected at your site, injuries from falls or falling objects may result, ranging from sprains and concussions to death.

Each employee who is constructing a leading edge six feet (1.8 meters) or more above lower levels shall be properly protected. Suitable protection may be provided by guardrail systems, safety net systems, or personal fall arrest systems.

Examples of leading-edge accidents:

- A roofer, handling a piece of fiberboard, backed up and tripped over a 7-inch parapet. He fell more than 50 feet to ground level and died of severe head injuries.
- Two connectors were erecting light-weight steel I-beams on the third floor of a 12-story building, 54 feet above the ground. One employee removed a choker sling from a beam and then attempted to place the sling onto a lower hook on a series of stringers. While the crawler tower crane was booming away from the steel, the wind moved the stringer into the beam the employee was standing on. The beam moved while the employee was trying to disengage the hook, causing him to lose his balance and fall to his death.

Hoist Areas

Each employee in a hoist area must be protected from falling 6 feet (1.8 meters) or more by guardrail systems, personal fall arrest systems, or other appropriate means. If guardrail systems or portions of those systems must be removed to facilitate hoisting operations, as during the landing of materials, and a worker must lean through the access opening or out over the edge of the access opening (to receive or guide equipment and materials, for example), that employee must be protected by one of the appropriate means.

Case Study: NIOSH FACE Report 91-15

A 36-year-old millwright foreman fell 41 feet to his death through an unguarded platform opening. At the time of the incident, an open-sided steel structure had been constructed to support eight air conditioning units on the platform. Four air-conditioning units had been installed and the fifth unit had been lifted into position by a crane. In order to level the unit, three millwrights were positioned on one side of the air-conditioning unit, while the victim was kneeling on the opposite side. The victim stood up and apparently tripped or stumbled and fell backwards landing on the steel grating of the platform walkway. Momentum from the fall caused the victim to roll into an adjacent opening which was about 17 feet long by 7 feet wide. The victim fell through the opening, struck a steel support crossbeam about 20 feet below, and fell an additional 21 feet to the ground. The victim was pronounced dead 4 hours later at the emergency room of a local hospital.

What do you think went wrong?

- The platform opening was not properly guarded
- The victim was not wearing a personal fall arrest system or any other tether
- The victim was out of reach of other workers who might have steadied him
- The platform may have been cluttered, leading to a trip and fall
- The steel grating may not have been level, creating an increased risk of rolling off

Formwork and Rebar

Formwork means using forms and framing to contain and shape wet concrete until it is self-supporting. Formwork includes the forms on or within which the concrete is poured and the frames and bracing that provide the forms stability.

Rebar or reinforcing bar work means placing steel bars or a mesh of steel wires used into reinforced concrete and masonry structures to strengthen the structures when they are under tension. During formwork or re-bar assembly, employees must be protected from falls of six feet or more by personal fall arrest systems, safety net systems, or positioning device systems.

Case Study: NIOSH FACE Report 90-25

On the day of this incident, two crews of three men each were working in different locations on the third floor of a building. The crews were screeding (smoothing off/leveling up) the concrete as it was being poured on the formwork. The victim (the owner) and one co-worker were using a 16-foot aluminum strike-off (a straightedge used to remove excess, freshly placed concrete, mortar, or plaster) to screed the concrete surface, while the third co-worker spread the concrete with a rake. The three workers were moving backwards as they worked on the concrete surface. An 8-inch by 8-inch support "H" column was located directly in the path of the victim. Approximately 2 feet behind the "H" column was a 48-inch by 91-inch floor opening designed to accommodate future ductwork for the heating, ventilation, and air-conditioning system. The floor opening was covered with a 1/2-inch-thick by 48-inch-wide by 92 1/2-inch-long section of particle board. The words "DO NOT STEP ON THIS" were painted on the surface of the covering. As the victim and fellow co-worker screeded the concrete near the "H" column, the victim moved backwards around the column and stepped on the floor opening cover. The cover bowed under the victim's weight, causing it to dislodge from its supports. The victim and cover fell through the opening 36 feet to the ground floor.

What do you think went wrong?

- The particle board cover was not sufficiently strong to support a worker who might accidentally step on it
- The column was not properly marked as an obstacle to be avoided while working
- The workers were not paying sufficient attention as they moved backwards across the floor

Ramps, Runways, and Walkways

It is common on a construction site for workers to use ramps and various kinds of walkways to move around the site and to carry materials and tools from one task to another. Each employee using ramps, runways, and other walkways must be protected from falling 6 feet (1.8 meters) or more.

Excavations

Excavations are needed to complete many construction tasks, such as pouring a foundation. Each employee at the edge of an excavation 6 feet (1.8 meters) or deeper must be protected from falling by guardrail systems, fences, barricades, or covers when the excavations are not readily seen because of plant growth or other visual barriers.

Where walkways are provided to permit employees to cross over excavations, guardrails are required on the walkway if it is 6 feet (1.8 meters) or more above the excavation.

Employers should also ensure there is a safe way to enter and exit any excavations and keep materials away from the edges of trenches. OSHA requires safe access to and egress from all excavations 4 feet (1.22 meters) or deeper, using ladders, steps, ramps, or other safe means of entry and exit. These devices must be located within 25 feet (7.6 meters) of all workers.

Dangerous Equipment

Each employee working above dangerous equipment must be protected from falling into or onto the dangerous equipment by guardrail systems or by equipment guards even in those cases where the fall distance is less than 6 feet (1.8m).

Overhand Bricklaying

Except as otherwise specified in the OSHA Fall Protection Standards, each employee performing overhand bricklaying and related work 6 feet (1.8 m) or more above lower levels must be protected from falling by guardrail systems, safety net systems, or personal fall arrest systems, or must work in a controlled access zone.

Note: Bricklaying operations performed on scaffolds are regulated by subpart L of OSHA 1926 – Scaffolds.

Low-Sloped Roof Work

OSHA defines a low-slope roof as a roof having a slope of less than or equal a ratio of 4 to 12 (4:12)—for example, 4 inches of vertical rise for every 12 inches of horizontal length. Each employee engaged in roofing activities on low-slope roofs with unprotected sides and edges six feet or more above lower levels must be protected from falling by guardrail systems, safety net systems, and personal fall arrest systems, or a combination of a warning line system and guardrail system, warning line system and safety net system, warning line system and personal fall arrest system, or warning line system and safety monitoring system.

Safety Monitoring System: a safety system in which a competent person is responsible for recognizing and warning employees of fall hazards.

Warning Line System: a barrier erected on a roof to warn employees that they are approaching an unprotected roof side or edge, and which designates an area in which roofing work may take place without the use of guardrails, body belts, or safety net systems to protect employees in the area.

Steep Roofs

OSHA defines a steep roof as having a slope of more than 4 to 12 (4:12). Each employee on a steep roof with unprotected sides and edges 6 feet (1.8 meters) or more above lower levels must be protected by guardrail systems with toe-boards, safety net systems, personal fall arrest systems, or by other appropriate means.

Case Study: NIOSH FACE Report 88-43

On the day of the incident, the victim and a co-worker were applying 4-foot by 8-foot pieces of sheeting to the roof of the garage portion of the dwelling. The roof had a 10:12 slope (i.e., it rose 10 inches for each foot in length). When the victim and his co-worker finished applying the sheeting, the victim prepared to cut a 6-inch overhang off the front of the garage roof. The victim lowered a rope to the ground where a second coworker attached a 7 1/4-inch circular saw. The victim pulled the saw up to the roof, then called to the second co-worker to throw him an extension cord. The victim caught the extension cord, but as he began to unwind and lower it back to the ground to be plugged in, he lost his balance. The victim fell off the roof but was able to grasp the toe board at the edge of the roof. The first co-worker tried to pull the victim back onto the roof but was unable to do so. The victim fell feet first through the open front of the dwelling, but as he fell, his feet struck a rafter. This caused his body to turn 180 degrees and he hit the concrete garage floor headfirst.

What do you think went wrong?

- Even though the worker was conducting leading-edge work without a guardrail or safety net, he neglected to use (or was not provided with) a personal fall arrest system (PFAS). Because the roof was steep, such a system was required.

Pre-Cast Concrete

Each employee who is 6 feet (1.8 meters) or more above lower levels while erecting pre-cast concrete members and related operations, such as grouting of pre-cast concrete members, must be protected by guardrail systems, safety net systems, or personal fall arrest systems.

Wall Openings

Each employee working on, at, above, or near wall openings (including those with chutes attached) where the outside bottom edge of the wall opening is 6 feet (1.8 meters) or more above lower levels and the inside bottom edge of the wall opening is less than 39 inches (1.0 meter) above the walking/working surface must be protected from falling by the use of a guardrail system, a safety net system, or a personal fall arrest system.

Case Study: MASSACHUSETTS FACE 97-MA-050-01

A 33-year-old male carpenter was fatally injured when he fell through the open side of the third floor of a structure being renovated from a factory into an office building. The victim was working with two co-workers to place a 300-pound wooden box beam onto the roof eight and one-half feet above the floor using a manual hoist. The hoist mechanism released, allowing the beam to fall and strike the victim, pushing him out the opening. He fell approximately 22 1/2 feet to the ground below, sustaining severe head injuries. Security personnel called for emergency medical assistance. The ambulance transported the victim to a nearby hospital, where he never regained consciousness and died two days later of his injuries.

What do you think went wrong?

- The open side of the structure was not properly protected with a guardrail or safety net
- The hoist may not have been properly maintained or inspected before use
- Workers may not have been trained properly in the use of the hoist and/or safety practices to maintain around openings

Types of Fall Protection—Passive Systems

Passive systems are protective systems that do not involve the actions of employees. Guardrails and safety nets are examples of passive fall protection systems. These systems are an important part of fall protection at a worksite because they can prevent falls even when the worker is not paying attention.

Guardrails

Guardrails are one the most common forms of fall protection. They can be constructed of wood, pipe, structural steel, or wire rope (flags must be attached to wire rope to increase visibility). Guardrails must have a top rail, a midrail, posts, and, when necessary, a toe board. Steel or plastic bands must not be used as top rails or midrails. Manila, plastic, or synthetic rope being used for top rails or midrails must be inspected as frequently as necessary to ensure that it continues to meet the mandated strength requirements.

Guardrail systems must be able to withstand a force of at least 200 pounds (890 N) applied within 2 inches (5.1 cm) of the top edge in any outward or downward direction, or at any point along the top edge. When the 200-pound test is applied in a downward direction, the top edge of the guardrail must not deflect to a height less than 39 inches (1.0 m) above the walking/working level. Guardrail system components selected and constructed in accordance with Appendix B to subpart M of OSHA 1926 will be deemed to meet this requirement.

Guardrails: Design Criteria

The top edge of a guardrail must be 42 inches (1.1 m) plus or minus 3 inches (8 cm) above the walking/working level. When conditions warrant, the height of the top edge may exceed the 45-inch height, provided the guardrail system meets all other necessary criteria.

Midrails, screens, mesh, or intermediate vertical members must be installed between the top edge of the guardrail system and the walking/working surface when there is no wall or parapet wall at least 21 inches (53 cm) high. Midrails, when used, should be installed at a height midway between the top edge of the guardrail system and the walking/working level. Top rails and midrails should be at least one-quarter inch (0.6 cm) in diameter or thickness to prevent cuts and lacerations. If wire rope is used for top rails, it should be flagged at intervals of 6 feet or less with high-visibility material.

For pipe railings, the posts, top rails, and intermediate railings should be at 1 ½ inches in diameter (schedule 40 pipe) with posts spaced not more than 8 feet (2.4 m) apart on the centers. For structural steel railings, the posts, top rails, and intermediate rails should be composed of at least 2-inch by 2-inch (5 cm x 10 cm) by 3/8-inch (1.1 cm) angles, with posts spaced not more than 8 feet (2.4 m) apart on the centers.

Screens and mesh, when used, should extend from the top rail to the walking/working level and along the entire opening. Intermediate members (such as balusters), when used between posts, should not be more than 19 inches (48 cm) apart.

Other structural members (such as additional midrails and architectural panels) must be installed such that there are no openings in the guardrail system that are more than 19 inches (.5m) wide.

Safety Net Systems

Safety net systems must be installed as close as practicable under the walking or working surface, but in no case more than 30 feet below the surface. The closer the net is to the surface, the smaller its overall size can be. If the net is not vertically more than 5 feet from the working level, it must extend outward from the outermost projection of the work by 8 feet in order to reliably catch falling objects or workers. If the net is vertically between 5 feet and 10 feet from the working level, it must extend outward from the outermost projection of the work by 10 feet. If the net is vertically more than 10 feet from the working level, it must extend outward from the outermost projection of the work by 13 feet.

Safety nets must be drop-tested at the jobsite after they are installed and before use, whenever relocated, after major repair, and at 6-month intervals after installation, if left in one place. These drop-tests consist of a 400-pound bag of sand 28-32 inches in diameter being dropped into the net from the highest working or walking surface, but not from less than 42 inches above that level.

Safety nets must have enough clearance beneath them to prevent contact with the surface or structures below when a load equal to the drop-test weight is dropped on them. They must be capable of absorbing an impact force that is equal to the drop test weight. All materials, scraps, equipment, and tools that have fallen in the net must be removed as soon as possible and at least before the next work shift.

The maximum size of each opening in the mesh of a safety net shall not exceed 36 square inches (230 cm2) or be longer than 6 inches (15 cm) on any side, and the opening, measured center-to-center of mesh ropes or webbing, should not be longer than 6 inches (15 cm). The net must have a border rope with a minimum breaking strength of at least 5,000 pounds. If safety nets are connected together, the connection must be as strong as the individual nets and hold them not more than 6 inches apart.

Covers

Covers are used to protect personnel from falling through holes in walking surfaces. Covers for holes in floors, roofs, and other walking/working surfaces must meet the following requirements:

- All covers must be secured when installed so as to prevent accidental displacement by the wind, equipment, or employees
- All covers should be color coded or marked with the word "HOLE" or "COVER" to provide warning of the hazard
- Covers located in roadways and vehicular aisles must be capable of supporting, without failure, at least twice the maximum axel load of the largest vehicle expected to cross over the cover

- All other covers shall be capable of supporting, without failure, at least twice the weight of employees, equipment, and materials that may be imposed on the cover at any one time

Note: This provision does not apply to cast iron manhole covers or steel grates used on streets or roadways.

Types of Fall Protection—Active Systems

Active fall protection systems require workers to be engaged in ensuring that proper protection is in use. This may include activities such as donning a full-body harness with an attached lanyard and attaching the lanyard to appropriate anchorage point.

Active systems are designed to operate in free fall situations and must be connected to other systems/components or activated to provide protection. Active systems are designed to protect employees from falls and other forces that can cause injury.

Personal Fall Arrest Systems (PFAS)

When used according to the manufacturer's instructions, a Personal Fall Arrest System (PFAS) can save a life should a fall occur. Generally, a PFAS consists of three major components:

- A full-body harness
- A shock-absorbing lanyard or retractable lifeline
- Secure anchors

Personal Fall Arrest Systems (PFAS) shall not be attached to a guardrail system or hoists. All components of a fall arrest system must be inspected by a competent person before each use and after any impact. Defective components must be immediately removed from service.

Fallen employees should immediately be rescued unless it is determined they can self-rescue. Suspension trauma, also known as harness hang syndrome or orthostatic intolerance, occurs after a worker has fallen into a fall arrest harness and is suspended in a hanging position until rescue arrives. When hanging in a fall harness, the leg straps support the body's weight. During this time, the leg straps of the fall protection harness crush the femoral arteries on the inside of the legs, cutting off blood circulation, a common type of suspension trauma.

When stopping a fall, a PFAS must:

- Limit the maximum arresting force on an employee to 1,800 pounds (8 kN) when used with a body harness
- Be rigged such that an employee can neither free fall more than 6 feet (1.8 m), nor contact any lower level
- Be attached to an anchor point capable of withstanding 5000 pounds of force or be designed, installed, and used as part of a complete personal fall arrest system that maintains a safety factor of at least 2 and is used under the supervision of a qualified person
- Bring an employee to a complete stop and limit maximum deceleration distance an employee travels to 3.5 feet (1.07 m)
- Have sufficient strength to withstand twice the potential impact energy of an employee free falling a distance of 6 feet (1.8 m), or the free fall distance permitted by the system, whichever is less

Protection from Falling Objects

When employees are exposed to falling objects, the employer must require employees to wear hardhats and implement one of the following measures:

Erect toe-boards, screens, or guardrail systems to prevent objects from falling from higher levels.

-or-

Erect a canopy structure and keep potential fall objects far enough from the edge so that those objects will not go over the edge if they are accidentally displaced.

-or-

Barricade the area to which objects could fall, prohibit employees from entering the barricaded area, and keep objects that may fall far enough away from the edge of a higher level so that those objects would not go over the edge if they were accidentally displaced.

Case Studies

Worker Falls from Scaffolding

This accident occurred during the construction of a new two-story wood frame house. The work on the day of the accident involved inserting pillars into the floor joists, which were then lifted by a mobile crane. Three workers were engaged in this assembly work on the ground, including the victim (a new employee) and two coworkers who carried out the elevated assembly work. The framing for the second-floor roof was completed in the morning after which the workers took a lunch break.

After the break, work resumed on the site and workers carried on with the same assignments. The incident happened when the victim went to stand on a scaffolding board that was stretched over the second-floor ceiling beam. As the worker stood on the board it suddenly fell onto the first-floor concrete foundation, killing the worker.

What do you think were some of the causes of the accident?

- The scaffolding board was not fixed
- No guardrail system or personal fall protection system was used by employees while working at heights greater than six feet
- No competent person for fall protection was onsite during the construction of this project
- While the victim had been newly employed the day of the accident, he was not given new hire safety orientation prior to starting work

Worker Struck by Falling Plywood

On a clear, windy morning a 24-year-old laborer was helping load trusses on the ground. 60 feet above them, coworkers were nailing 8 ft. by 4 ft. plywood to the roof of a newly constructed commercial construction project. The coworkers on the roof only had one more sheet of plywood to nail down and they would be finished with this side of the building. As one worker on the roof moved to hand off the last piece of plywood to a second worker, a gust of wind ripped the plywood from the first worker's hands, and it started to slide down the roof. The first worker stated in a panic he tried to jump on the plywood to catch it but his yo-yo retractable fall protection lanyard of 6 feet grasped him and stopped his slide, allowing the plywood to continue off the roof. The wind caught the plywood as it slid towards the edge of roof and flung it 30 feet from the building where the laborer was loading the trusses. The plywood struck the back of the laborer's head just below his protective hard hat knocking him to the ground.

What do you think were some of the causes of the accident?

- Not enough attention was paid to the weather conditions
- Workers reacted with panic, potentially circumventing their training on best practices, or else demonstrating a deficiency in training
- No canopy structure was erected to catch falling objects
- The area around the building that was kept free of other workers should have extended out a sufficient distance to prevent accidents like this one

Lesson Summary

Falls are the leading cause of fatalities in the construction industry. Because falling bodies accelerate so quickly, a fall does not have to be from a great height to cause severe injuries or death. It is crucial to have adequate fall protection in a variety of settings around a worksite, including unprotected sides and edges, holes, hoist areas, excavations, roofs, and wall openings.

There are two types of fall protection: active systems and passive systems. Active systems, such as personal fall arrest systems (PFASs), require the worker to be actively engaged with the safety mechanism. Passive systems, on the other hand, include guardrails and safety nets, and can protect workers whether or not they are actively monitoring their safety.

It is additionally important to protect workers from falling objects at many worksites. Toe boards, nets, and canopy structures are some common controls. Barricades may also be used to keep people out of the areas where falling objects pose a risk.

Lesson 2: Inspection and Safety Monitoring Systems

Lesson Focus

At the end of this lesson, students will be able to:

- Inspect fall protection equipment
- Describe the components of personal fall-arrest systems
- Describe the components of positioning device systems
- Describe the requirements of a safety monitoring system
- Understand when a fall protection plan may be used
- Explain the necessary training for inspection and safety monitoring

Inspecting Fall Protection Equipment

Fall protection equipment must be inspected before each use for tears, cuts, burns, and abrasions. Distorted hooks, damaged springs, deformed eyelets or D-rings, and any other non-functioning parts must be replaced before using the equipment. Clean any dirt, grease, oil, corrosives, or acids that may have gotten onto the equipment, and be sure to read the manufacturer’s labels.

Personal Fall-Arrest Systems (PFASs)

A personal fall-arrest system consists of a full body harness and the associated hardware that slows a worker's rate of descent and keeps him or her from hitting the ground. Personal fall arrest systems are different from positioning devices, such as body belts, which allow employees to work on elevated vertical surfaces, such as walls and telephone poles, with both hands free.

Harnesses

Harness systems are constructed of synthetic fibers. When used as a PFAS, only harnesses that encompass the entire body (a full body harness) are permitted because only those will distribute the weight across the waist, pelvis, and thighs. Body belts cannot be used for fall arrest.

Lanyards

Lanyards are flexible lines made of synthetic fiber or wire rope that have a connector at each end for connecting the body harness to a deceleration device, lifeline, or anchorage. Lanyards and vertical lifelines must have a minimum breaking strength of 5000 pounds.

The following are some of the types of lanyards:

- **Self-retracting:** Eliminates excess slack in the lanyard (cable, rope, or web). Self-retracting lifelines are deceleration devices that contain a drum-wound strap or wire rope that moves in and out of the case under the tension posed by employee movement, much like the shoulder strap on a car seat belt. If an employee falls, the inertial mechanism automatically locks the drum, arrests the fall, and limits the free fall distance to two feet.
- **Shock absorbing:** Slows and eventually stops descent and absorbs the forces. Energy absorbing lanyards, or "rip stitch" lanyards as they are sometimes called, consist of a fabric strap that is folded back and forth on itself in an S-shaped zigzag pattern, then stitched along the edge. The shock imposed by a fall breaks the stitching and the webbing unfolds like an accordion to dissipate the energy and absorb the impact load.
- **Synthetic rope:** Absorbs some of the force by stretching
- **Synthetic webbing:** Strong but not flexible (absorbs little force)

Lifelines

Lifelines consist of flexible material connected at one or both ends to an anchorage point. There are two types of lifelines:

Vertical: hangs vertically (5000-pound minimum breaking strength).

Horizontal: Connects at both points to stretch horizontally (serves as connection point for other components of PFAS; the total system must have a safety factor of two and be capable of locking in both directions on the lifeline).

Snap Hooks

Snap hooks are used to connect lanyards to compatible D-rings on a body harness. They must be connected to a harness or anchorage point only. Snap hooks and D-rings must have tensile strength of 5000 pounds and be proof tested to a minimal tensile load of 3600 pounds. All snap hooks must have a locking mechanism that remains closed and locked until unlocked and pressed open for connection or disconnection.

Anchorage Points

The anchorage point is most effective when it is above the employee's head, located such that it does not allow an employee to fall more than 6 feet. Anchorages used for the attachment of personal fall arrest equipment must be independent of any anchorage being used to support or suspend platforms, and it must be capable of supporting at least 5,000 pounds per employee attached. It should be designed, installed, and used under the supervision of a qualified person as part of a complete personal fall arrest system that maintains a safety factor of at least two.

Positioning Device Systems

A positioning device system is a body belt or body harness system rigged to allow an employee to be supported on an elevated vertical surface, such as a wall, and work with both hands free while leaning. Positioning device systems must be inspected before each use for defects, and defective components must be removed from service. They should be rigged such that an employee cannot free fall more than 2 feet (0.9 m) and secured to an anchorage capable of supporting at least twice the potential impact load of an employee's fall or 3,000 pounds, whichever is greater.

A positioning device system is not a fall arrest system! A positioning device system is designed to allow an employee to safely work at heights. A fall arrest system is designed to stop an employee who has already begun to fall. They should not be interchanged.

Warning Line System

A warning line system is an awareness device erected on a roof to warn employees that they are approaching an unprotected roof side or edge, and which designates an area in which roofing work may take place without the use of guardrail, body belt, or safety net systems to protect employees in the area.

Warning line systems and their use shall comply with the following provisions:

- The warning line shall be erected around all sides of the roof work area.
- Warning lines shall consist of rope, wire, chains, or supporting stanchions, which are used to warn employees of an unprotected edge, and must be erected as follows:
- It must be flagged at not more than 6 foot intervals with high-visibility materials.
- The rope, wire, or chain must be rigged and supported such that:
- Its lowest point (including sag) is no less than 34 inches from walking/working surface.
- Its highest point no more than 39 inches from surface.
- Stanchions, with rope, chain, or wire attached, must be able to withstand, without tipping over, a force of 16 pounds applied horizontally against the stanchion, 30 inches (.8 m) above the walking/working surface, perpendicular to the warning line, and in the direction of the floor, roof, or platform edge.
- The rope, wire, or chain used must have a minimum tensile strength of 500 pounds.
- No employee is permitted between roof's edge and a warning line unless the employee is performing roof work in that area.

Note: A warning line system is used mainly on roofs, where the use of PFAS is impractical.

Controlled Access Zone (CAZ)

A controlled access zone (CAZ) is an area at a worksite where certain hazardous work is taking place without the use of guardrails, PFASs, or safety nets. Only qualified personnel involved in the task (such as overhead bricklaying) are permitted in the CAZ. Ropes, wires, tapes, or chains with supporting stanchions are used to designate the area, which should be erected between 6 and 25 feet away from any unprotected edge.

Safety Monitoring System

Employers must designate a competent person to monitor the safety of other employees, and the employer has the duty to ensure that the safety monitor complies with the following requirements:

- He/she must be competent to recognize fall hazards.
- He/she must warn employees when it appears that they are unaware of a fall hazard or are acting in an unsafe manner.
- He/she must be on the same walking/working surface and within visual sighting distance of employees being monitored.
- He/she must be close enough to communicate orally with the employees.
- He/she must not have other responsibilities which could take attention from the monitoring responsibilities.

Each employee working in a controlled access zone must be directed to comply with all instructions from the monitor. It is recommended that employers have a written plan for using the safety monitoring system to address the identification of the monitor, the roles of employees in the monitoring system, and training for using the monitoring system.

Falling Objects

Employers are required to protect their employees from falling objects. A common method for doing so involves the installation of toe boards (at least 3.5 inches wide) along the edges of the overhead walking/working surfaces for a distance sufficient to protect persons working below. The toe boards must be capable of withstanding, without failure, a force of at least 50 pounds applied in any downward or outward direction at any point along the toe board. Where tools, equipment, or materials are piled higher than the top edge of a toe board, paneling or screening should be erected from the walking/working surface or toe board to the top of a guardrail system's top rail or midrail, for a distance sufficient to protect employees below.

Fall Protection Plan

The fall protection plan option is available only to employees engaged in leading edge work, precast concrete erection work, or residential construction work who can demonstrate that it is unfeasible or it creates a greater hazard to use conventional fall protection equipment.

A Fall Protection Plan must be prepared by a qualified person and developed specifically for each site. It should be maintained up to date and any changes to the plan must be approved by a qualified person. A copy of the plan with all approved changes must be maintained at the site. The fall protection plan should document the reasons why the use of conventional fall protection systems (guardrail systems, personal fall arrest systems, or safety nets systems) is infeasible or why their use would create a greater hazard.

Elements of a Fall Protection Plan

A fall protection plan must consist of the following elements:

- Statement of Policy
- Fall Protection Systems to be Used
- Implementation of Plan
- Enforcement
- Accident Investigation
- Changes to the Plan

Training

All employees exposed to fall hazards must receive training by a competent person to address the nature of fall hazards in the work area, procedures for erecting, maintaining, disassembling, and inspecting fall protection systems to be used, and the use and operation of fall arrest equipment.

An employee training program must cover the role of an employee in a safety monitoring system (when used), limitations on the use of mechanical equipment for low-slop roofs, the roles of employees in fall protection plans, the procedures for handling and storing equipment, and the standard contained in 29 CFR 1926.500-503.

Case Study

Fall during the Assembly of a Suspended Scaffold for Bridge Painting

The following is a case study of an accident involving falls and fall protection. The accident occurred while suspended scaffold was being installed for painting bridge girders. The suspended scaffold was comprised of the main pipes supported by chains hung from the bridge girders and single tubes that extended perpendicular to the main pipes. The plan called for installing two layers of scaffold. Measures to prevent a fall when this scaffold was completed included safety netting that was stretched below the bottom of the lower scaffold platform to the right and left of bridge girders to make personnel movement easy. Two lift trucks, each with a maximum work height of 15 meters, were being used for this work. Each truck was moved after each scaffold section was complete.

On the day of the accident, three workers exited onto the ground from one of the lift trucks in order to move the vehicle. However, the truck could not be moved forward because the truck tires were stuck in river sand. Five other workers, who had their safety belts on and attached to the hanging chains, were on scaffold boards watching and waiting for the truck to be moved.

After several minutes, some of these workers who were tied off on the scaffold heard a loud sound and turned in time to see a fellow worker attempting to catch one of the chains as he fell beneath the single tubes. The worker had been attempting to adjust the chains by himself. He fell while attempting to adjust the hanging chain or during his movement from the scaffold board to a flange below.

What do you think were some of the causes of the accident?

Although the victim had been wearing a safety harness while waiting on the scaffold, when he moved to adjust the hanging chains, he was no longer wearing it and it wasn't tied off. Workers should have waited on the ground while the truck was being moved, and not at an elevated site that posed a danger of falling. The operations chief for scaffolding erection also did not provide proper supervision regarding the proper use of personal fall arrest systems.

Lesson Summary

A positioning device system is a body belt or body harness system rigged to allow an employee to be supported on an elevated vertical surface, such as a wall, and work with both hands free while leaning.

A warning line system is an awareness device erected on a roof to warn employees that they are approaching an unprotected roof side or edge, and which designates an area in which roofing work may take place without the use of guardrail, body belt, or safety net systems to protect employees in the area.

A Fall Protection Plan must be prepared by a qualified person and developed specifically for each site. The Fall Protection Plan must be maintained up to date. Any changes to the plan must be approved by a qualified person. A copy of the plan with all approved changes must be maintained at the site. The fall protection plan shall document the reasons why the use of conventional fall protection systems (guardrail systems, personal fall arrest systems, or safety nets systems) is infeasible or why their use would create a greater hazard.

Lesson 3: Electrocution

Lesson Focus

At the end of this lesson, students will be able to:

- Explain how electricity works and its dangers

- Identify the types of electrical injuries
- Understand how to control electrical hazards

OSHA's electrical standards address electrical workplace hazards, equipment, work practices, safety practices, and more. Employees working on, near, or around electricity may be exposed to dangers such as electric shock, electrocution, burns, fires, and explosions. The objective of the standards is to minimize the potential hazard by specifying design characteristics when installing and using electrical equipment and systems.

Electricity

Electrical current is the flow of electrons from a voltage source back to its source. It requires a source of voltage, a circuit path through a conductor, and a load that uses the current flow as work. An example would be a battery connected to a lightbulb. The battery is the voltage source, the lightbulb is the load, and the wires connecting the bulb to the positive and negative terminals are the circuit path.

Working with electricity can be dangerous. In 2019, there were 166 electrical fatalities, with almost half occurring in the construction or related industries. Additionally, construction has the highest rate of fatal electrical injuries, a rate approximately 7 times the rate averaged across all industries.

Safety Tips

- When working with or near electricity, always assume that all overhead wires are energized at lethal voltages. Never assume that a wire is safe to touch, even if it is down or appears to be insulated. Never touch a fallen overhead power line; instead, call the electric utility company to report fallen electrical lines.
- Stay at least 10 feet (3 meters) away from overhead wires during cleanup and other activities. Many lines require a much more significant safe working distance. If working at heights or handling long objects, survey the area before starting work for the presence of overhead wires.
- If an overhead wire falls across your vehicle while you are driving, stay inside the vehicle and continue to drive away from the line. If the engine stalls, do not leave your vehicle. Warn people not to touch the vehicle or the wire. Call or ask someone to call the local electric utility company and emergency services.
- Never operate electrical equipment while you are standing in water.
- Never perform repairs to electrical cords or equipment unless qualified and authorized.
- Have a qualified electrician inspect electrical equipment that has gotten wet before energizing it.
- If working in damp locations, inspect electric cords and equipment to ensure that they are in good condition and free of defects, and use a ground-fault circuit interrupter (GFCI).
- Always use caution when working near electricity.

Electrical Injuries

The following are the main types of electrical injuries:

Direct Injuries:

- Electrical shock and related symptoms resulting from the shock (e.g., tissue damage, neurological disorders, muscle contractions that can cause falls and other injuries, etc.)
- Electrocution (death due to electrical shock)
- Burns
- Arc flash/blast (usually resulting in burns, concussion injuries, etc.)

Indirect Injuries:

- Falls
- Back Injuries
- Cuts to the hands

Electrical Shock

An electrical shock is received when electrical current passes through the body. This occurs when your body completes an electrical circuit that includes a voltage source, such as when touching an exposed energized circuit with one part of your body and a grounded point with another part of your body, or when contacting two different energized conductors at the same time.

The severity of the shock depends on the path of the current through the body, the amount of current flowing through the body (amps), and the duration of the shocking current through the body.

Remember, low voltage does not mean low hazard!

Levels of Electric Shock

mA*	Affect
0.5–3	Tingling sensation
3–20	Muscle contractions and pain
10–40	"Let go" threshold may be exceeded. Worker may be unable to release a live circuit
20–150	Painful shock with severe muscle contraction, breathing may become difficult
30–75	Possible respiratory paralysis
100–200	Possible ventricular fibrillation affecting the heart
200–4,000	Likely heart damage or stoppage

*mA = milliampere = 1/1,000 of an ampere

The overcurrent at which a typical fuse or circuit breaker opens is 15,000 milliamps (15 amps). These devices are designed to protect the electrical system—not people! By the time these devices open, death or very serious injury is likely to have already occurred.

Burns and Arc Flash

Burns are among the most common shock-related injuries. Burns can occur when you touch exposed energized electrical wiring or equipment. Many burns also occur as a result of arc flash, which refers to a flashover of electric current that leaves its intended path and travels through the air from one conductor to another, or to ground. Burns resulting from arc flash or other means often occur on the hands, although other parts of the body may be affected, and may be very serious injuries that require immediate attention. In the case of arc flash, additional internal injuries may occur with the burns as a result of the concussive force sometimes produced. The heat of an arc flash is four times that of the surface of the sun.

Falls

Electric shock can also cause indirect injuries. Workers on ladders and in elevated locations who experience a shock can fall, resulting in serious injury or death.

Electrical Hazards and How to Control Them

Electrical accidents are caused by many factors, including unsafe equipment and/or installation, unsafe workplace environments, and unsafe work practices. The following sections outline some common electrical hazards and the appropriate controls.

Exposed Electrical Parts

Live parts of electric equipment operating at 50 volts or more must be guarded against accidental contact, which may be done using cabinets or other forms of enclosures, or by any of the following means:

- By location in a room, vault, or similar enclosure that is accessible only to qualified persons
- By partitions or screens so arranged that only qualified persons will have access to the space within reach of the live parts. Any openings in such partitions or screens shall be so sized and located that persons are not likely to come into accidental contact with the live parts or to bring conducting objects into contact with them
- By location on a balcony, gallery, or platform so elevated and arranged as to exclude unqualified persons
- By elevation of at least eight feet or more above the floor or other working surface and so installed as to exclude unqualified persons

Conductors Entering Boxes, Cabinets, or Fittings

Conductors entering boxes, cabinets, or fittings must be protected from abrasion. Openings through which conductors enter must be effectively closed. Unused openings in cabinets, boxes, and fittings also must be effectively closed.

Covers and Canopies

All pull boxes, junction boxes, and fittings must be equipped with covers. If metal covers are used, they should be grounded. In energized installations, each outlet box should have a cover, faceplate, or fixture canopy.

Overhead Power Lines

Overhead power lines usually are not insulated, meaning equipment or workers that comes into contact with them are at risk of electrical shock. The following are examples of the equipment most likely to come into contact with power lines at a worksite:

- Cranes
- Ladders
- Scaffolds
- Backhoes
- Scissors lifts
- Raised dump truck beds
- Paint rollers

Overhead and buried power lines are especially hazardous because they may carry extremely high voltage. Fatal electrocution is the main risk, but burns and falls from elevation are also hazards. Using tools and equipment that can come into contact with power lines increases the risk.

Power line hazards can be avoided if the following precautions are taken:

- A distance from the power lines of at least ten feet is maintained. A much greater distance may be required, depending on the voltage capacity of the lines.
- Warning signs are posted.
- Power lines are assumed to be energized.
- Wood or fiberglass ladders, not metal ladders, are used.
- Special training and personal protective equipment are provided to power line workers.
- Power lines are de-energized and/or shielded when necessary.

Inadequate Wiring

A wire that is too small for the current is a hazard. If a portable tool with an extension cord, for instance, has a wire too small for the tool, it will draw more current than the cord is designed to handle, with the potential of causing overheating and a possible fire, all without tripping the circuit breaker. The circuit breaker could be the right size for the circuit but not for the smaller-wire extension cord.

Use the correct wire! The wire you should use depends on the operation, building materials, electrical load, and environmental factors. Use fixed cords rather than flexible cords when possible. If using an extension cord, use the correct one. The OSHA standards require flexible cords to be designed for hard or extra-hard usage. These ratings are to be indelibly marked at approximately every 24" on the cord. Because deterioration occurs more rapidly in cords, which are not rugged enough for construction conditions, the NEC and OSHA have specified the types of cords to use in a construction environment. This rule designates the types of cords that must be used for various applications, including portable tools, appliances, and temporary and portable lights. The cords are designated HARD and EXTRA HARD SERVICE.

Defective Cords and Wires

Sometimes, the insulation inside of an electrical tool or appliance is damaged. When insulation is damaged, exposed metal parts may become energized if a live wire inside touches them. Electric hand tools that are old, damaged, or misused may have damaged insulation inside. If you touch damaged power tools or other equipment, you may receive a shock. You are more likely to receive a shock if the tool is not grounded or double-insulated.

Cords are most commonly damaged as a result of:

- Aging
- Door or window edges
- Staples or fastenings
- Abrasion from adjacent materials
- Activity in the area
- Improper use
- Lifting tools/equipment with the cords
- Pulling on cords to unplug

Improper use of cords can also cause shocks, burns, or fire. The normal wear and tear on extension and flexible cords at your site can loosen or expose wires, creating hazardous conditions. Cords that are not of the three-wire type, not designed for hard-usage, or that have been modified, increase your risk of contacting electrical current.

The following controls will help protect workers from electric shock as a result of defective cords or wires:

- Live wires should be insulated where required
- Cords should be checked before use
- Only cords that are three-wire type should be used
- Only cords marked for hard or extra-hard usage should be used (designated by "S" at the beginning of the cord type; SJ indicates junior hard usage)
- Only cords, connection devices, and fittings equipped with strain relief should be used
- Cords should be removed by pulling on the plugs, not on the cords

- Cords not marked for hard or extra-hard use, or which have been modified, must be taken out of service immediately

Flexible cords and cables must be protected from damage! DO NOT use flexible wiring where frequent inspection would be difficult or where damage would be likely. Flexible cords must not be run through holes in walls, ceilings, or floors; run through doorways, windows, or similar openings (unless physically protected); or hidden in walls, ceilings, floors, conduit, or other raceways.

Arc Flash Hazard

An arc flash is a MUCH more significant event than a typical short circuit. It occurs when a flashover of electric current leaves the intended path and travels through the air from one conductor to another, or to ground. The results of an arc flash are often very violent, with a large amount of concentrated radiant energy exploding outward from electrical equipment, creating pressure waves that can damage a person's hearing, a high intensity flash that can damage eyesight, and a superheated ball of gas that can severely burn a worker's body and even melt metal. Temperatures of arc flashes have been recorded as high as 35,000 °F.

An arc flash, and its resulting release of energy, can only occur if an arc between two differences of electrical potential occurs. A difference of electrical potential (voltage reading) exists between any two-phase conductors, or any phase conductor and a grounded part (in grounded systems only). An arc flash can be caused by accidental contact with electrical components, an accumulation of dust, corrosion, dropped tools, improper installation of equipment, and improper work procedures.

When an arc occurs, current that is available from the source of electrical energy passes from one conductor to the other conductor at the point of the arc fault. Because the travel of current in an arc flash is not contained within a conductor, but travels through free air, the effects of the energy are not contained. This energy is referred to as "incident energy."

Examples of Electrical Accidents

- Two workers were moving an aluminum ladder. One of them was electrocuted when the ladder came into contact with overhead power lines.
- A worker was raising a mast on a water well drilling truck when the mast came in contact with high voltage overhead lines, electrocuting the worker.
- A worker was electrocuted when the boom of a rotary drilling truck contacted an overhead power line. The victim was standing at the controls, lowering the boom, and was thrown several feet away from the truck.
- A worker was fatally injured when he was electrocuted and fell to the concrete floor while working from an 8' fiberglass step ladder. He was changing an energized ballast on a two-bulb florescent light fixture, located approximately 11' 6" off the ground.

Lesson Summary

Electrical current is the flow of electrons from a voltage source back to its source. It requires a source of voltage, a circuit path through a conductor, and a load that uses the current flow as work. An example would be a battery connected to a lightbulb. The battery is the voltage source, the lightbulb is the load, and the wires connecting the bulb to the positive and negative terminals are the circuit path.

Electrical injuries on a worksite often result from exposed electrical parts. Any such parts should be guarded against accidental contact with workers. Another common source of electrical injury comes from contact with uninsulated overhead powerlines. Power lines should always be assumed to be live, and proper signage should indicate where power lines are located on the worksite. Inadequate or defective wiring can also cause electrical injuries, including through arc flash. In an arc flash, electricity arcs through the air between two conductors or between a conductor and ground. Severe burns and other injuries can result.

Lesson 4: Electrical Hazards—Other Preventive Measures

Lesson Focus

At the end of this lesson, students will be able to:

- Describe electrical hazards related to grounding and overloaded circuits
- Explain power tool requirements
- Identify when electrical hazards exist
- Explain how to lock-out and tag-out circuits
- Describe safety practices related to working with electricity
- Explain the precautions necessary when doing energized work
- Identify the necessary personal protective equipment (PPE) for electrical work
- Explain how to safely use batteries
- Describe the necessary training elements for working with electricity

Improper Grounding

Grounding creates a low-resistance path from a tool to the earth to disperse any unwanted current, preventing it from finding a more damaging path to ground, such as through a person. When a short or lightning occurs, the excess energy flows to the ground, helping protect you from electrical shock, injury, and death. Tools plugged into improperly grounded circuits may become energized, creating a hazard.

Control: Ground Tools and Equipment

Always properly ground power supply systems, electrical circuits, and electrical equipment. Inspect electrical systems before each use to ensure that the path to ground is continuous. Don't remove ground prongs from tools or extension cords and don't use tools or extension cords with missing or damaged ground plugs. Be sure to ground exposed metal parts of equipment.

Control: Use a Ground-Fault Circuit Interrupter (GFCI)

A ground fault circuit interrupter (GFCI) helps protect you from shock by detecting differences in current as small as 5 milliamps between the amount of electricity flowing into a circuit and the amount flowing out of the circuit. A GFCI shuts off electricity in as little as 1/40th of a second if a ground fault is detected.

Control: Assured Equipment Grounding Conductor Program (AEGCP)

An assured equipment grounding conductor program (AEGCP) includes a written description of specific procedures adopted by the employer to help prevent electric shock. It should be implemented by a competent person designated by the employer. As part of the program, each cord set, attachment cap, plug, and receptacle of cord sets, and any equipment connected by cord and plug, except cord sets and receptacles which are fixed and not exposed to damage, shall be visually inspected before each day's use for external defects, such as deformed or missing pins or insulation damage, and for indications of possible internal damage. Equipment found damaged or defective should not be used until repaired. Other tests and inspections should include tests for continuity and the correct attachment of the grounding conductor. Records of the tests should be kept and made available.

The AEGCP on construction sites must cover all cord sets, receptacles not part of a building or structure, and equipment connected by plug and cord that is available for use.

Overloaded Circuits

Too many devices plugged into a circuit can result in heated wires and possibly fire. Wire insulation melting can cause arcing and fire in the area where the overload exists, including inside a wall.

Electrical protective devices are designed to automatically open a circuit if excess current from overload or ground-fault is detected, shutting off the electricity. Electrical protective devices include ground fault circuit interrupters (GFCIs), fuses, and circuit breakers.

Ground-Fault Circuit Interrupter (GFCI): A device for the protection of personnel that functions to de-energize a circuit within an established period of time when a current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the entire supply circuit.

Fuses: (Over 600 volts, nominal) Overcurrent protective devices with a fusible opening in the circuit that is heated and severed by the passage of overcurrent through that part, breaking the circuit.

Circuit Breakers:

(600 volts or less, nominal) Devices designed to manually open and close a circuit, and to open the circuit automatically on a predetermined overcurrent without damage when properly used within its rating.

(Over 600 volts, nominal) Devices capable of making, carrying, and breaking currents under normal circuit conditions, and also capable of making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions, such as those of short circuit.

Power Tool Requirements

Power tools must:

Be grounded through a 3-wire cord with one wire going to ground,

-or-

Be double insulated,

-or-

Be powered by a low-voltage isolation transformer,

-or-

Be powered by a properly designed and self-contained battery power unit.

Tool Safety Tips

The following are some safety tips to consider when using power tools:

- Use gloves and appropriate footwear when using tools and when safe and appropriate to do so.
- Store tools in a dry place when not in use.
- Don't use tools in wet/damp conditions unless they are designed for this purpose.
- Keep working areas well lit.
- Ensure that tools and cords do not create a tripping hazard.
- Don't carry a tool by the cord.
- Don't yank the cord to disconnect the tool from the electrical source.
- Keep cords away from heat, oil, and sharp edges.
- Disconnect tools when not in use and when changing accessories such as blades and bits.
- Remove damaged tools from use.
- Avoid accidental starting. Do not hold fingers on the power switch or button while carrying a plugged-in tool or while tagging damaged tools.

Preventing Electrical Hazards

The following measures should be taken to prevent electrical hazards associated with the use of power tools:

- Inspect tools before use
- Use the right tool correctly
- Protect your tools from damage
- Use double insulated tools when appropriate

Temporary Lights

Temporary lights should be protected from contact and damage, and they should not be suspended by cords unless designed for that.

Clues that Electrical Hazards Exist

The following are some clues that can help you determine whether an electrical hazard exists:

- When there are tripped circuit breakers or blown fuses
- When tools, wires, cords, connections, or junction boxes are warm to the touch
- When a GFCI shuts off a circuit
- When there is worn or frayed insulation around a wire or a connection

More Information: If a GFCI trips while you are using a power tool, there is a problem. Don't keep resetting the GFCI and continue to work. You must evaluate the "clue" and decide what action should be taken to control the hazard.

Locking Out and Tagging Out of Circuits

The following steps must be performed when locking out and tagging out circuits:

- Apply locks to the power source after de-energizing
- Verify circuit is de-energized by testing with known functioning meters
- Tag deactivated controls and power sources
- Tag de-energized equipment and circuits at all points where they can be energized
- Tags must identify equipment or circuits being worked on

Safety-Related Work Practices

To protect workers from electrical shock:

- Use barriers and guards to prevent passage through areas of exposed energized equipment

- Pre-plan work, post hazard warnings, and use protective measures
- Keep working spaces and walkways clear of cords
- Use special insulated tools when working on fuses with energized terminals.
- Don't use worn or frayed cords and cables
- Don't fasten extension cords with staples; hang the cords from nails or suspend them using wire

Employers must not allow employees to work near live parts of electrical circuits unless the employees are protected by one of the following means:

- De-energizing and grounding the parts
- Guarding the part by insulation
- Any other effective and approved means

In work areas where the exact location of underground electrical power lines is unknown, employees using jack hammers, bars, or other hand tools that may contact the lines must be protected by insulating gloves, aprons, or other protective clothing that will provide equivalent electrical protection.

Flexible cords must be connected to devices and fittings so that strain relief is provided which will prevent pull from being directly transmitted to joints or terminal screws. Equipment or circuits that are de-energized must be rendered inoperative and must have appropriate locks and tags attached at all points where the equipment or circuits could be energized.

As appropriate, the employer must ensure that all wiring components and equipment in specific hazardous locations are maintained in a dust-tight, dust-ignition-proof, or explosion-proof condition. There shall be no loose or missing screws, gaskets, threaded connections, seals, or other impairments to a tight condition.

Avoiding Wet Conditions

The following are important points to consider in avoiding wet conditions:

- If you touch a live wire or other electrical component while standing in even a small puddle of water, you may get a shock.
- Damaged insulation, equipment, or tools can expose you to live electrical parts.
- Improperly grounded metal switch plates and ceiling lights are especially hazardous in wet conditions.
- Wet clothing, high humidity, and perspiration increase your chances of being electrocuted.

Energized Work

Energized work must be done in safe work conditions or the reasons for not doing so must be properly documented and justified. To justify energized work, an employer must demonstrate that de-energizing introduces additional or increased hazards, or is infeasible due to equipment design or operational limitations.

Work on circuits with voltages less than 50 volts may be performed in an energized state if a proper assessment has been completed and there is no increased exposure to electrical burns or explosion risks due to arcs.

Examples of increased or additional hazards that could provide justification to work on energized circuits over 50 volts include interruption of life support equipment, deactivation of emergency alarm systems, or the shutdown of hazardous location ventilation equipment.

Energized Electrical Work Permit

If justification for energized work is demonstrated, then the work can be performed only after proper completion of a written permit.

Elements of an Energized Electrical Work Permit include the following:

- Description and location of the circuit and the equipment involved
- Justification for energized work
- List of the safe work practices to be applied
- Results of a shock risk assessment
- Determination of the shock protection boundaries as noted in NFPA 70E
- Results of an arc flash analysis
- Required PPE
- Means used to restrict entry of qualified personnel into the work area
- Completion of a job briefing, including a discussion of job specific hazards
- Authorized and signed energized work approval

Exemptions to a Work Permit

Work that is performed on or near live parts by qualified persons and related to tasks such as testing, troubleshooting, and voltage measuring may not require an energized electrical work permit as long as the appropriate safe work practices and required PPE are used.

NFPA 70E Complements OSHA Regulations

In lieu of detailed specifications, OSHA recognizes, and in some cases refers to, industry consensus standards such as the National Fire Protection Association's (NFPA) 70E as a tool for assisting with regulatory compliance. A copy of NFPA 70E is considered by many to be a critical addition to every employer's safety library.

The National Fire Protection Association provides free access to read and review their standards, including 70E. This service allows users to view the standards after registering with the association. This access is available on the NFPA website. Accessing this standard is critical to a full and complete understanding of the definitions, work practices, controls, documentation, and equipment necessary to provide a safe work site and to ensure compliance with the applicable OSHA standards.

Approach Boundaries to Energized Parts

Approach boundaries are perimeters at various distances from a potentially hazardous energized part designed to keep employees safe by requiring certain safety measures be taken when any worker must cross these boundaries. The following are some types of approach boundaries related to electrical work:

Arc Flash Boundary: In those activities or conditions where the hazard of an arc flash is present, the arc flash boundary is that distance from the source that an exposed individual could receive second degree burns. In other words, the individual is potentially in harm's way.

Limited Approach Boundary: In those activities or conditions where the hazard of an electrical shock is presented by energized electrical components, this is the distance at which exposure to a shock is possible.

Restricted Approach Boundary: This is the distance at which there is a heightened possibility of electrical shock from energized electrical components, due to a combination of existing conditions, personnel movement, and proximity.

Note: Any personnel working on energized parts must have training on the requirements of NFPA 70E. Please complete the additional training program on this code prior to working on energized parts. Detailed information regarding the application of the boundaries can be found in NFPA 70E. Annex C, Section 1.2.3 of this standard provides an excellent graphical representation of the boundaries which may be useful for training and enforcement activities.

Preventing Electrical Hazards—Personal Protective Equipment (PPE)

When it is necessary to handle or come close to wires with a potentially live electrical charge, it is essential to use proper insulating personal protective equipment (PPE) to help protect employees from coming into contact with the hazardous electrical energy.

The following measures can provide protection from electrical hazards:

- Proper foot protection
- Rubber insulating gloves, hoods, sleeves, matting, and blankets
- Hard hat (insulated—nonconductive)

Safety Shoes and Boots

Safety shoes and boots should be nonconductive and should protect your feet from completing an electrical circuit to ground. Safety shoes can help protect against open circuits of up to 600 volts in dry conditions. These shoes should be used with other insulating equipment and in connection with active precautions to reduce or eliminate the potential for providing a path for hazardous electrical energy.

Hard Hats

Specific types of hard hats are needed when performing electrical work. A "Class E" electrical/utility type hard hat protects against falling objects and high-voltage shock and burns. Wearing a hard hat provides protection for your head of up to 20,000 volts.

Type of PPE for Arc Flash Protection

When work must be performed within an Arc Flash Boundary, a flash hazard analysis determines and documents the incident energy exposure of the worker in cal/cm^2. Flame-resistant (FR) clothing and PPE must be used by anyone crossing any part of her or his body into the Arc Flash Boundary as based on the incident energy calculation.

Training

Employees working with electric equipment must be trained in safe work practices, including:

- De-energizing electric equipment before inspecting or repairing
- Using cords, cables, and electric tools that are in good repair
- Lockout/tagout recognition and procedures
- Using appropriate protective equipment

De-Energizing Electrical Equipment

Accidental or unexpected starting of electrical equipment can cause injury or death. Before any inspections or repairs are made, the current must be turned off at the source and this location locked in the "OFF" position. Additionally, the switch or controls of the machine, or other equipment being locked out of service, must be tagged securely to show which equipment or circuits are being worked on.

A De-Energizing or Lockout / Tag out Program requires the following:

- Application of locks to all power sources, including all potential sources of electrical energy, after each source has been de-energized
- Application of a tag on each de-energized control identifying who has locked the control out, and instructing others to not unlock or re-energize the control
- Proper training for all workers involved in or potentially impacted by the de-energization of the equipment. Included in this training should be the following groups of employees:
    - **Authorized employees**—those who lock out and/or tag out machines or equipment in order to perform maintenance or servicing
    - **Affected employees**—those whose job requires them to use or operate equipment or machines being maintained or serviced

- **All other employees**—who work or operate in areas where lockout/tagout procedures are used

Batteries and Battery Charging

The following are important guidelines for safely using batteries on a worksite:

- Batteries of the unsealed type must be located in enclosures with outside vents or in well-ventilated rooms and shall be arranged so as to prevent the escape of fumes, gases, or electrolyte spray into other areas.
- Ventilation must be provided to ensure diffusion of the gases from the battery and to prevent the accumulation of an explosive mixture.
- Racks and trays should be substantial and treated to make them resistant to the electrolyte.
- Floors should be of acid resistant construction unless protected from acid accumulations.
- Face shields, aprons, and rubber gloves must be provided for workers handling acids or batteries.
- Facilities for quick drenching of the eyes and body must be provided within 25 feet (7.62 m) of battery handling areas.
- Facilities should be provided for flushing and neutralizing spilled electrolyte and for fire protection.
- Battery charging installations should be located in areas designated for that purpose.
- Charging apparatus should be protected from damage by trucks.
- When batteries are being charged, the vent caps should be kept in place to avoid electrolyte spray. Vent caps should be maintained in functioning condition.

Lesson Summary

Grounding refers to the practice of providing a safe, low-resistance path for electricity to return to ground should a fault occur. Proper grounding techniques and safety precautions, such as using a ground fault circuit interrupter (GFCI) are crucial to protecting employees. Overloaded circuits present one example of a hazard that requires proper grounding and a GFCI to prevent. Power tools must also be properly grounded, or else double-insulated or battery-powered. Tools, including temporary lights, should always be inspected before use.

Other important safety-related work practices include locking out and tagging out deenergized circuits, keeping workspaces clear of cords and wires, and only using safe (not frayed or worn) extension cords.

Energized work can be particularly dangerous, since the current continues to flow while the work is done. Energized work can only be performed under certain conditions when deenergizing the components is not possible. An energized work permit is also required.

Employees should be provided with the proper personal protective equipment (PPE) when necessary. For electrical work, this could include safety shoes and belts, rubber insulating gloves, and class E hard hats.

Lesson 5: Struck by Hazards

Lesson Focus

At the end of this lesson, students will be able to:

- Define a struck-by hazard
- Explain the dangers and controls associated with heavy vehicles
- Explain the dangers and controls associated with falling or flying objects
- Explain the dangers and controls associated with constructing masonry walls

What is the Struck-By Hazard?

According to OSHA, being struck by objects is a leading cause of construction-related deaths (only falls rank higher). In 2016, there were 93 struck-by fatalities in the construction industry, or just under 10% of all construction deaths. Safety and health programs must include ways to limit or eliminate the many causes of struck-by accidents.

Typically, struck-by accidents are associated with vehicles, falling or flying objects, or masonry walls.

The Danger from Heavy Vehicles

If vehicular safety practices are not followed at a work site, workers are at risk of being pinned (caught) in between construction vehicles and walls or stationary surfaces, struck by swinging equipment, crushed beneath overturned vehicles, or many other similar accidents. When working near a public roadway, workers are additionally exposed to being struck by trucks, cars, or other vehicle traffic.

Important engineering controls that help avoid hazards from heavy vehicles include the following measures:

- Always install, use, and maintain vehicle back-up alarms.
- Station flaggers behind vehicles that have obstructed rear views.
- Keep non-essential workers away from areas of vehicle use.
- Keep workers away from temporary overhead activities.
- Place barriers and warning signs around hazardous operations and public roadways.
- **Never** put yourself between moving or fixed objects.
- **Always** wear bright, highly visible clothing when working near equipment and vehicles.