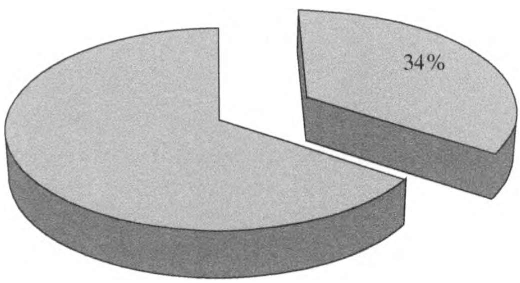
C H A P T E R 1 8

Construction



Percentage of OSHA citations addressing this subject

This book would not be complete without a chapter on the construction industry and its relationship to the field of safety and health. Why is this industry singled out, whereas the book has otherwise taken a general approach to the subject? There are two principal reasons. One is that the construction industry has long been recognized as more hazardous than most. Workplace installations are temporary, and economics dictate a different approach to such facilities as guardrails and stairways. The very nature of the work dictates that risks be taken that are not necessary in general industry. This added risk alone would ensure that OSHA would take a special interest in construction, but there is another reason for OSHA's emphasis that is probably more pervasive than the risk factor. The Occupational Safety and Health Act of 1970 was preceded by the Construction Safety Act, Public Law 91–54. The result of this sequence is that federal standards for construction safety were already in place at the time of passage of the more general OSHA law. The OSHA law provided for adoption of "existing federal standards" as national consensus standards, bypassing the lengthy promulgation procedures required for new standards. Thus, a set of rather comprehensive standards for construction (Part 29 CFR 1926) has been maintained separately from the General Industry (Part 29 CFR 1910) standards. The construction standard is a classic example of "vertical" standards, as compared with OSHA's general approach of adopting "horizontal" standards, as was covered in Chapter 4. The safety and health manager for a construction company should look first to the construction vertical standards, but should be aware that if OSHA cannot find a construction standard that covers a given hazard found at a construction site, the compliance officer is free to turn to the general industry standards to write a citation. This places a new dimension on the problem of bringing a construction industry into compliance with standards. In Chapter 4, we saw a pie chart that revealed that approximately 7% of all OSHA citations to the construction industry were from the General Industry Standard, not the Construction Standard.

This chapter is primarily for safety and health managers of construction companies, but even the general industry safety and health manager should find the information herein useful. Almost every industry has occasional remodeling or expansion projects that result in construction. Even if the company contracts out the construction project, what goes on is still important to the company because its own employees can become exposed to hazards created by the contract construction personnel. Such hazards can be both physical and legal.

GENERAL FACILITIES

Guardrails and Controlled Decking Zones

In Chapter 7, guardrails were seen as the solution to open-sided floors or platforms in general industry. In construction, the situation is a little more complex. In construction, the floor or platform may be in the process of being built, so it may not be practical to have the same solution to the fall hazard problem. The very nature of construction requires that personnel approach the edge of an open-sided floor or platform. This is not to say that the construction worker should not be protected; however, the strategy for making the exposure safe may be different.

The most straightforward approach to protecting the construction worker is to erect a temporary guardrail, with the same strength and design characteristics as for general industry guardrails. When construction workers are using stilts to do their jobs, such as in drywall installation, the required height of the guardrails to protect these personnel is increased by the height of the stilts. The construction standard requires guardrails to protect workers when the fall distance is 6 feet or more. Compare this standard with the requirement that general industry guardrails must protect workers from falls 4 feet or more. The reason for this difference will be explained later in this chapter.

During the construction of a new floor, a different solution to the problem is necessary. The OSHA standards have identified areas known as *Controlled Decking Zones* (CDZs) for the erection of new floors in steel erection. Workers must be adequately trained to work in CDZs so that they recognize and heed the hazards of working near exposed edges of floors. Standards also require that the CDZ area be clearly marked with perimeter demarcation using control lines which act essentially as awareness barriers introduced in Chapter 15. The control lines should be strong and taut, that is, their minimum breaking strength should be at least 200 pounds and they should not sag to less than 39 inches from the floor. Personnel who are not directly engaged in work at the leading edge of a floor under construction must be prohibited from entering the CDZ. CDZs are limited to 3000 square feet (914.4 m^2) and must not be more than 90 feet (27.4 m) wide or 90 feet (27.4 m) from any leading edge. Although the standards for CDZs are mandatory for steel erection, the concepts can be used in general construction for the erection of new floors with exposed edges.

Besides the exposed edges of new floors, construction sites present the hazards of holes in the floor and even the ceiling. Besides holes in the floor, skylights present hazards of holes in the roof on which workers may be working. Skylights are especially hazardous because they may be covered with a translucent material that may appear suitable for walking. Unfortunately, workers have often made the mistake of stepping onto a skylight and discovering tragically late that their weight is too much for the skylight and they fall through. Many workers have been killed by such accidents. On construction projects holes in the floor may also present hazards of objects or tools falling through the holes onto workers below. This is another reason for requiring hard hats on construction sites. In addition, hole covers are needed, or other means of protecting against this hazard must be implemented. Finally, the hazard of exposed elevator shafts must be considered. An elevator shaft is, after all, a hole with an exposed edge. Many workers and even the public, when visiting construction sites, have fallen into elevator shafts.

Lighting

Curiously, there are standards for adequate lighting on construction sites, specifying minimum illumination intensities for various areas, whereas general industry has no such general[1] table of intensities. The reason perhaps has to do with trip hazards and pitfalls (in the literal sense of the word) common to construction sites, hazards that are intensified by poor illumination. The minimum illumination standard of 5 footcandles is really quite low for general construction area lighting, and the standard drops even lower, to 3 footcandles for concrete placement, excavation and waste areas, accessways, active storage areas, loading platforms, and refueling and field maintenance areas. Lighting requirements are higher for most construction shops and indoor areas.

Materials Handling and Storage

The real structural test of most buildings is during their own construction. The heaviest load a floor will probably ever support is the stacked materials used during its own construction. Planning is needed to prevent overloading and possible collapse. All nails should be withdrawn from used lumber before it is stacked.

Rigging equipment for material handling such as chain, rope, and wire rope is, unfortunately, often used until failure. If failure does occur on a construction site, the safety and health manager must be prepared to explain why, because rigging equipment is required to be inspected prior to use on *each shift*.

Disposal of scrap material requires vigilance throughout the construction phase. It is difficult to concentrate on scrap and waste removal when working on a tight project completion schedule, but haphazard scrap accumulation is not only unsafe, but also slows progress. Enclosed chutes are needed for dropping materials from distances of greater than 20 feet. In addition, some scrap material, such as asbestos, requires special protection.

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[1]Although OSHA does not have a general illumination standard for appropriate levels of lighting, there is a somewhat general table in the standard for Hazardous Waste Operations and Emergency Response, as was discussed in Chapter 7.

PERSONAL PROTECTIVE EQUIPMENT

Construction requirements for personal protective equipment are similar to those for general industry, the principal difference being one of emphasis.

Hard Hats

At the top of the list is head protection; indeed, the hard hat is a symbol of the construction industry. So obvious is the absence of a hard hat in a construction work crew that the hard-hat rule can be a source of embarrassment to worker and manager alike. Only general conditions are laid out to describe *when* hard hats are needed. This lays the responsibility for the decision upon the safety and health manager. In Chapter 12, it was seen that discretion is advised in setting up a hard-hat rule. The important issue here is to be sure that the rule, once established, is followed.

Hearing Protection

It may surprise some readers that hearing protection is a concern for *construction*, but construction work often involves damaging levels of noise. Consider the noise levels and durations of exposures of the compressed-air "jackhammer," for example.

Eye and Face Protection

The greatest concern for construction workers' eyes is for mechanical injury, as from using structural steel riveters, grinders, powder-actuated tools, woodworking tools, concrete nozzles, and other spark- and chip-producing equipment. Surprisingly, construction workers can even be exposed to lasers used as tools for checking steel girder alignment and deflection in bridges and buildings. Construction also frequently requires electric arc welding which requires eye and face protection and protective clothing as well.

Fall Protection

On the bases of both fatalities and injuries, falls are probably the greatest hazard in construction work. Where general industry has a permanent wall, construction may have only a guardrail. Where general industry has a permanent guardrail, construction may have a temporary guardrail or perhaps will have no protective structure at all. Where general industry has a permanent stairway, construction may have a temporary ladder. General industry fixed ladders may have cages or ladder safety devices; construction ladders often have no such safety devices.

As was seen in earlier chapters of this book, first priority should be given to an engineering solution to fall hazards. Before resorting to personal protective equipment it may be practical to install a temporary guardrail. A word of caution is in order, however. Recalling one of the pitfalls of the engineering approach, the hazard can actually be made worse if the temporary guardrail engenders a false sense of security. When a worker relies upon a guardrail, imagine the tragedy that will likely occur if the guardrail fails and yields to the stress applied to it. OSHA requires that a guardrail (whether permanent or temporary) withstand a side load of 200 pounds applied to the top of the rail. Figure 18.1 illustrates the tremendous stress placed upon the base of a temporary

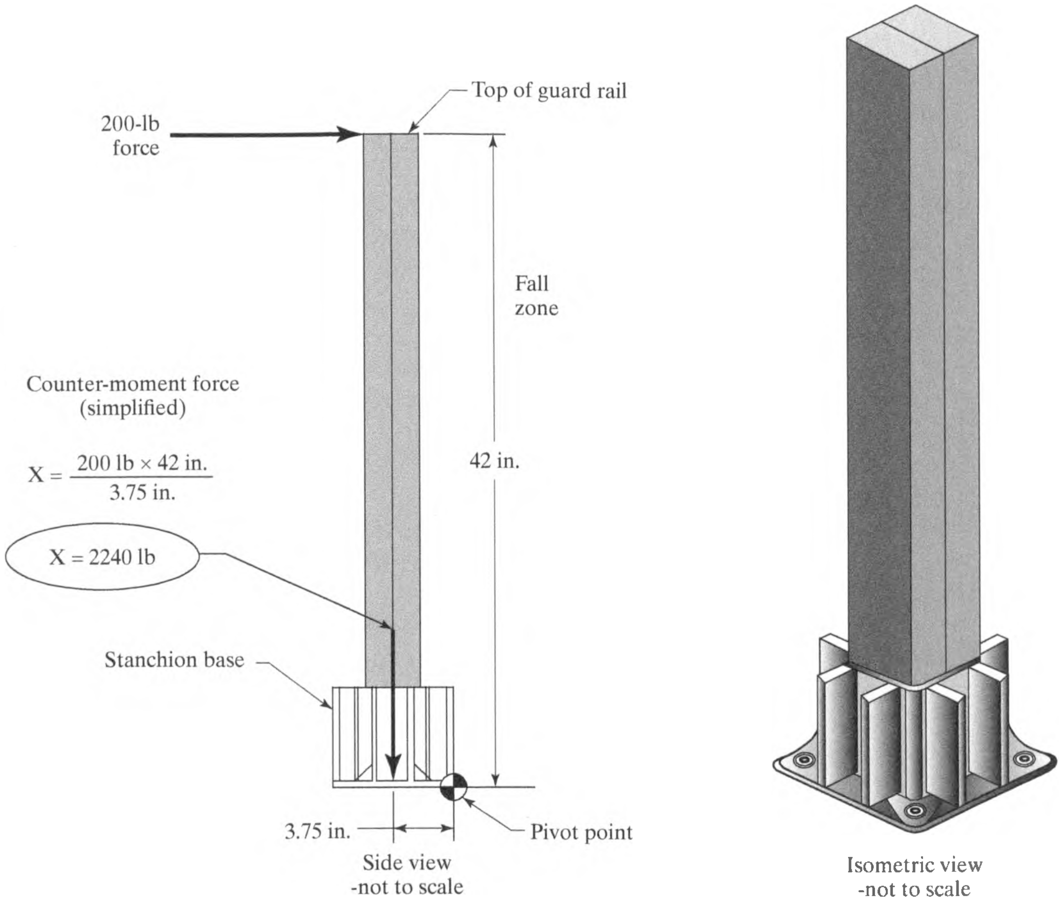


FIGURE 18.1

Guardrail Counter-Moment Force Analysis. (*Note:* guardrails constructed from wood 2 × 4 lumber. Base provided courtesy of Safety Boot, Incorporated. Drawing provided by Erica Asfahl).

guardrail when the top rail is subjected to the OSHA specified limit. If temporary guardrails are installed, the contractor should have assurance that the guardrail will withstand the prescribed OSHA stress limit. Commercially available stanchion bases for temporary guardrails should have engineering documentation to assure the purchaser that the base will withstand the prescribed load.

Personal protective equipment is the answer to many construction industry fall hazards, simply because protection by other means may be awkward or even impossible. Body harnesses and lanyards tied to lifelines are essential to the safety of construction workers subject to fall hazards.

One mistake made in selecting fall protection equipment is to improvise with ordinary leather belts and ropes. An ordinary leather belt and hardware will not satisfy the specified 4000-pound tensile test for fall protection belt hardware. No one weighs

4000 pounds, but what matters in a fall is the shock load, which can be several times as great as the ordinary dead weight. A falling 200-pound person can therefore result in $\frac{1}{2}$ to 1 ton of force on the fall protection system. Using a safety factor of approximately 4, it is easy to see why the standard specifies a 4000-pound tensile load limit.

The lanyard is that part of the fall protection system that attaches to the body harness on one end and the lifeline or structure on the other. The lanyard must have a nominal breaking strength of 5400 pounds. The applicable standard specifies "$\frac{1}{2}$-inch nylon or equivalent." Beware of substituting materials of equivalent breaking strength to $\frac{1}{2}$-inch nylon. Tensile or breaking strength is not the only consideration in selecting a lanyard. A certain resiliency or elasticity exists with artificial fiber ropes that lessens the shock load when arresting a fall.

An important point with safety lanyards is that they must not be too long. The standard specifies "a maximum length to provide for a fall of no greater than 6 feet." The rationale is that there is no point in breaking a fall with the lanyard if the worker has already fallen so far that the shock of the rope will be lethal. However, the standard is often misunderstood on this point. Note carefully that the wording just quoted does not limit the lanyard length to 6 feet. Figure 18.2 clarifies this point. Even though lanyard length varies from 6 feet in diagram (a) to 12 feet in diagram (b), the actual falling distance is less than 6 feet in both cases.

The reader at this point might ask the question, "Why 6 feet when back in Chapter 7 the standard for guardrails for buildings is to protect for falls of 4 feet? Is this not an inconsistency?" It is true that the fall distances are different, but there is a rationale for this difference. In construction, the difficulty of setting lanyard lengths to protect against 4 feet falls instead of 6 feet and resetting them every time the construction worker changes position on the job is much greater than for the erection of permanent guardrails. This is a direct application of the cost-benefit analysis methods introduced in Chapter 3. The judgment of where to apply safety measures and how much, depends on the benefits to be derived and the costs of the safety measure. It is

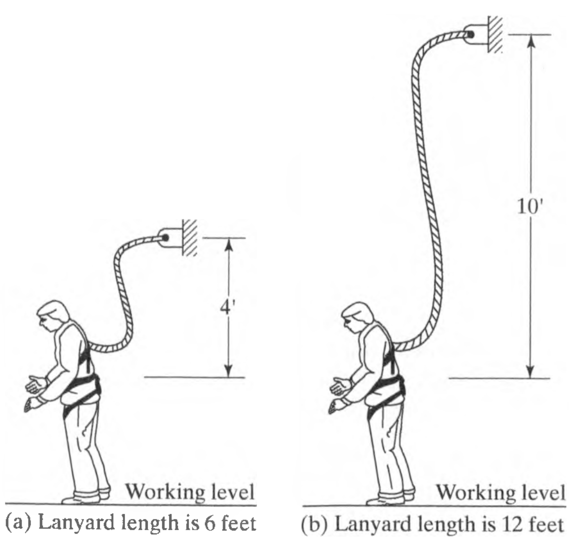


FIGURE 18.2

Maximum lanyard length must provide for a fall of no greater than 6 feet.

interesting to note that a similar difference exists between the standard for temporary construction guardrails and permanent general industry guardrails. There is always a trade-off. This trade-off can be seen to apply to the writing of the standards as well.

One difficulty with limiting the length of lanyards is that they restrict the movement of the worker. Therefore, as with other systems that are designed for protection of the individual, the worker finds a way to get around the system. A common practice in the construction industry is to use "cheater cables," a sort of "extension cord" for a safety lanyard. The worker has a sense of security because he or she is still attached to the lifeline by means of a lanyard plus the cheater. However, this sense of security is somewhat misleading, because an accidental fall might be of too great a distance, resulting in a fatal shock load to the worker—even if the worker does not hit the ground or lower platform level.

One difficulty is attempting to attach a lanyard to a vertical lifeline, especially when the lanyard must be adjusted upward or downward on the lifeline, such as in use with a scaffold. It is necessary for the attachment to slide easily when this is intended, but the attachment must lock and hold if the worker falls. There are mechanical devices, but an easy-to-tie knot for this purpose is the triple rolling hitch shown in Figure 18.3.

Fall protection is usually considered from the standpoint of height, but working over or near water presents a different hazard. Even the best of swimmers will have difficulty with a fall into water if he or she is fully dressed and perhaps burdened by tools, equipment, or materials such as rivets or bolts. If the water is rather cold, the danger of hypothermia increases the drowning hazard.

Drowning hazards are taken very seriously in federal standards, which require

1. life jackets or buoyant work vests,
2. ring buoys every 200 feet, and
3. a lifesaving skiff

whenever employees work over or near water and a danger of drowning exists.

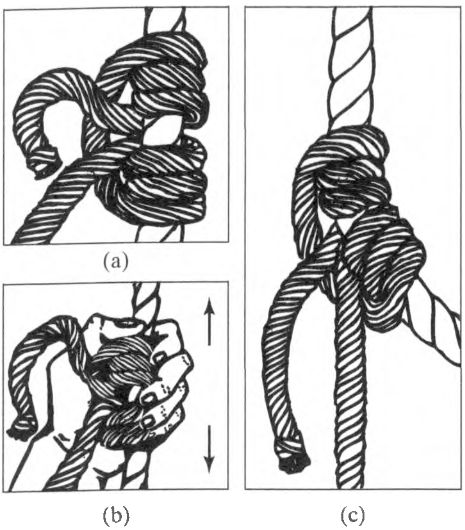


FIGURE 18.3

(a) Triple rolling hitch tied with free end of lanyard; (b) easily raised and lowered slipping on cable or lifeline; (c) when the lanyard is pulled tight, as in a fall, the triple rolling hitch will not slip on the lifeline.

FIRE PROTECTION

From a property-loss standpoint, fires are more dangerous after a building is completed, but to protect construction workers, fire hazards must also be controlled *during* construction. Construction sites have somewhat more latitude in distributing fire extinguishers than do general industries. Even an ordinary garden hose may be used in place of fire extinguishers on construction sites. However, there are so many restrictions on such use of a garden hose that most safety and health managers will regret having considered this alternative.

The biggest problem with fire prevention during construction is the handling of flammable liquids. For ordinary flammable liquids such as gasoline, quantities handled must be no more than 1 gallon unless approved metal safety cans are used. Approved metal safety cans must be used even for quantities up to 1 gallon unless the flammable liquid is used out of its *original* container. Containers should be kept off stairways and away from exits and aisles.

TOOLS

It has been well publicized that mushroomed heads on chisels, wedges, and other impact tools are unsafe. The hazard is that a sliver of metal can break off and cause a severe eye injury, even total loss of sight. Another problem with hand tools is defective handles, in particular loose hammer heads.

Construction sites may employ pneumatic tools, such as jackhammers, staplers, or nailers. Pneumatic tools need to be secured to the hose by some positive means to prevent accidental disconnection. Hoses larger than $\frac{1}{2}$ inch inside diameter need a pressure-reducer device to prevent whip action in case of hose failure. Figure 18.4 is a diagram of a pressure-reducer device for this purpose. It is a simple in-line device, usually placed between the hose and the compressor. Unfortunately, the device reduces the overall capacity of the system. Operating at full capacity, as from several tools operating at once, the pressure downstream from the device becomes so low that the device (a spring-loaded valve) begins to close as if the downstream line had ruptured. This shuts off or nearly shuts off the supply of air to the tools, making the system useless at that capacity. The result is that the worker removes the device from the line, and often as not, it is soon lost. This is a sore point with many construction safety and health managers. Training and education, including videos of a dangerous, loose pneumatic hose under pressure, will help to illustrate to workers the utility of the pressure-reducer device provided for the workers' protection.

Some construction applications are being found for hydraulically operated tools, especially in the public-utility construction field. Hydraulic tools operate under the same

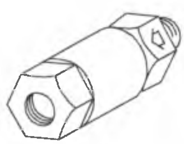


FIGURE 18.4

In-line device for preventing whip action in event of pneumatic hose failure.

principle as pneumatic tools but use liquids instead of air as the medium. Fluid pressures in these tools can reach 3000 psi gauge, approximately 20 times the maximum pressure achievable with pneumatic tools. Such tremendous pressures give hydraulic tools much greater power than pneumatic tools, but a hazard can exist if operating pressure limits of the equipment are exceeded. Under the criterion of occupational noise, however, hydraulic tools have a safety and health advantage over pneumatic tools. Additional hazards of hydraulic fluids are electrical conductivity and fire. These hazards tend to conflict in that the more fire resistant fluids are electrical conductors. When working in construction and alteration of electric-utility transmission and distribution systems, the hazard of electrical conductivity is more serious than the hazard of fire. The hydraulic fluids used for the insulated sections of derrick trucks, aerial lifts, and hydraulic tools that are used on or around energized lines and equipment for power transmission and distribution are required to be of the insulating type. The fluids for hydraulic tools used in other applications are required to be fire resistant.

Powder-actuated tools carry an explosive charge to provide the driving force. The applications of these tools are increasing because they are both fast and effective. Driving fasteners into concrete, masonry, or steel demands large, accurately placed impact forces. Powder-actuated tools are able to provide these forces in a convenient way, speeding up production on construction projects. However, together with this speed, force, and convenience come safety hazards.

A powder-actuated tool looks and operates very much like a handgun, as can be seen in Figure 18.5. Even the powder cartridges look like bullets for a gun. In powder-actuated tools, however, the projectile is separate from the cartridge, as shown in Figure 18.5.

In some ways, powder-actuated tools are even more dangerous than handguns. Powder-actuated tools are capable of handling a variety of cartridges with a wide range of power ratings. These cartridges must be selected with care by a knowledgeable person. Insufficient power will fail to do the job, but too much power may drive the fastener completely through the material and kill a coworker in another room. (This has actually happened.) To protect against such hazards and for convenience, cartridges are color coded for easy identification. Metal-cased cartridges are available in a range

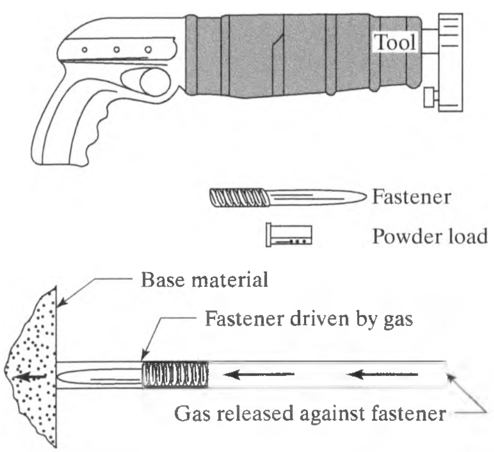


FIGURE 18.5

Powder-actuated fastening tool (*Source*: NIOSH 78-178A, Power Actuated Fastening Tools 1978).

TABLE 18.1 Color Identification for Cased Power Loads for Powder-Actuated Tools

Power level	Case color	Load color	
1	Brass	Gray	Lightest
2	Brass	Brown	↑
3	Brass	Green	
4	Brass	Yellow	
5	Brass	Red	
6	Brass	Purple	
7	Nickel	Gray	
8	Nickel	Brown	
9	Nickel	Green	
10	Nickel	Yellow	
11	Nickel	Red	↓
12	Nickel	Purple	Heaviest

of 12 different power ratings, as shown in Table 18.1. It may be necessary to back the material with a substance that will prevent the fastener from passing completely through.

Knowledge and judgment are also required in avoiding very hard or brittle materials, such as cast iron, glazed tile, surface-hardened steel, glass block, live rock, face brick, or hollow tile. If the material is spalled or cracked by an unsatisfactory previous fastening, the new fastening must be driven elsewhere. Fasteners driven too close to the edge of the material can cause explosive chipping of the material at the edge. Obviously, eye protection is always needed when using powder-actuated tools.

ELECTRICAL

Construction workers are often in close contact with ground and frequently work in wet locations under adverse conditions. Electrocution ranks with falls near the top of the list of causes of fatalities among construction workers.

A principal requirement on construction sites is that all 15- and 20-ampere outlets have either ground-fault circuit-interruptor (GFCI) protection or a program of equipment ground-conductor assurance, including inspection, testing, and recordkeeping. The safety and health manager in a construction company is faced with a decision between the two alternatives, and the paragraphs that follow are intended to assist in making that decision.

The purpose and operating principle of the GFCI were discussed in Chapter 17. The hazards of electrical shock by faults to ground are greater on construction sites than in the general industrial workplace. Because of the increased hazards, the *National Electrical Code*® specified GFCIs for construction, but not for general industry, although they would be of value in any electric circuit serving hand-held appliances or tools. Chapter 17 illustrated how GFCIs work and showed a residential-type receptacle equipped with a GFCI.

It seems that almost every safety device has its drawbacks, and the GFCI is no exception. The GFCI closely monitors any difference in current flow between the ground and neutral conductors, as low as fractions of a milliampere. However, there are ways in which these currents can be unbalanced when no hazard exists. Tiny amounts of current leakage to ground occur for quite innocent reasons. Damp or weakened insulation might produce tiny currents in various locations. Even an extension cord that is too long can create a condition of capacitance between the conductor and the ground, resulting in a tiny leak. Although none of these conditions of itself is a significant hazard, the cumulative effect is one that may be great enough to trip the GFCI, shutting down the entire circuit. This is so-called *nuisance tripping* and has made the GFCI a controversial issue in the construction industry.

Chapter 17 mentioned a permissible alternative to the GFCI: the careful maintenance of the grounding conductors of electrical equipment. Such maintenance includes regular inspections and records of these inspections. The idea behind the "assured equipment grounding-conductor program" is that if an electrical tool shorts to the case or handle, the third-wire grounding system will shunt the current to quickly throw the circuit breaker. A good grounding conductor can therefore provide protection similar to the GFCI.

The assured equipment grounding-conductor program is appealing to many construction companies because they can avoid buying the GFCI equipment. They can also avoid the nuisance tripping of the GFCIs discussed earlier. However, although the costs are less tangible, they nevertheless exist with the grounding assurance alternative. It takes instruments and time to test the grounding conductors, and the business of recordkeeping always involves intangible costs. An economic impact analysis of the two alternatives has been made that estimated a cost of compliance of $87.5 million for purchase, installation, and first-year maintenance of GFCIs. The study estimated for the alternative assured equipment grounding-conductor program a similar cost of $36 to $43.8 million. Inflation changes absolute annual cost estimates, but the relative difference between the costs of the two alternatives suggests that the assured equipment grounding-conductor program is cheaper.

Temporary lighting is an electrical problem on construction sites more than in general industry. Often seen are ordinary incandescent bulbs suspended from electrical cords. Cords and lights that are suspended in this way must actually be *designed* for this purpose; all electric cords for temporary lighting must be heavy duty, and insulation must be maintained in a safe condition. To prevent accidental contact, bulbs must be guarded, unless the construction of the reflector is such that the bulbs are deeply recessed.

A construction site is a profusion of temporary conditions, and electrical cords or extension cords strung about the area are a common sight. Unfortunately, the area is also visited by heavy-duty vehicles such as excavation equipment, heavily loaded trucks, and very heavy concrete delivery trucks. The situation is too hazardous to permit electrical cords to pass through work areas unless covered or elevated to protect them from hazardous damage. No splices are permitted in a flexible cord unless properly molded or vulcanized.

LADDERS AND SCAFFOLDS

The "care and use" provisions for ladders are important for construction ladders, just as they are for ladders used in general industry, a topic that was covered in Chapter 7. Construction ladders have some differences, however, that have caused some problems.

Job-Made Ladders

Construction companies often make their own ladders, and such ladders are not illegal if made properly. The first requirement is to determine how many persons will be needing the ladder. If simultaneous two-way traffic is anticipated, a conventional ladder will not work, and a double-cleat ladder, as shown in Figure 18.6, should be used. In fact, if the ladder is the only means of access or exit from a working area for 25 or more employees, the double-cleat ladder is *mandatory,* unless two ladders are provided.

The biggest mistake made in building job-made or homemade ladders is to fail to inset the cleats into the side rails (see Figure 18.7). It is much more trouble to inset the cleats or use filler blocks than to simply nail the cleats in place, but the security and stability of the cleats are increased many times by this additional effort to make the ladder safe.

Scaffolds

The subject of scaffolds can become somewhat technical, and these technical details can be very important. The safety and health manager will find it useful, and in some cases imperative, to obtain the services of a registered professional engineer. This is one area in which the credential as well as the knowledge can be quite useful.

One of the technical aspects of scaffolds is safety factor. Design safety factor for scaffolds and their components is a factor of four. This factor increases to a factor of six for the suspension ropes supporting the suspended type of scaffolding. The application of counterbalances, tie-downs, footings, and the allowance for wind loading all can be quite technical, and an engineering evaluation is advisable.

The safety and health manager may be frustrated by the many bewildering names of scaffolds listed in applicable construction standards. However, the majority of the

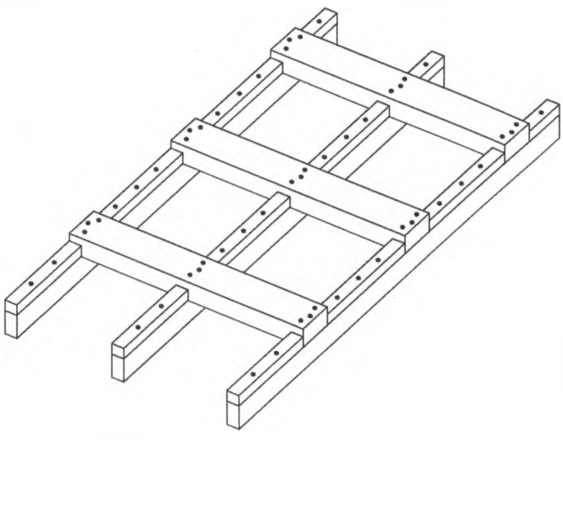


FIGURE 18.6

Double-cleat ladder for simultaneous two-way traffic.

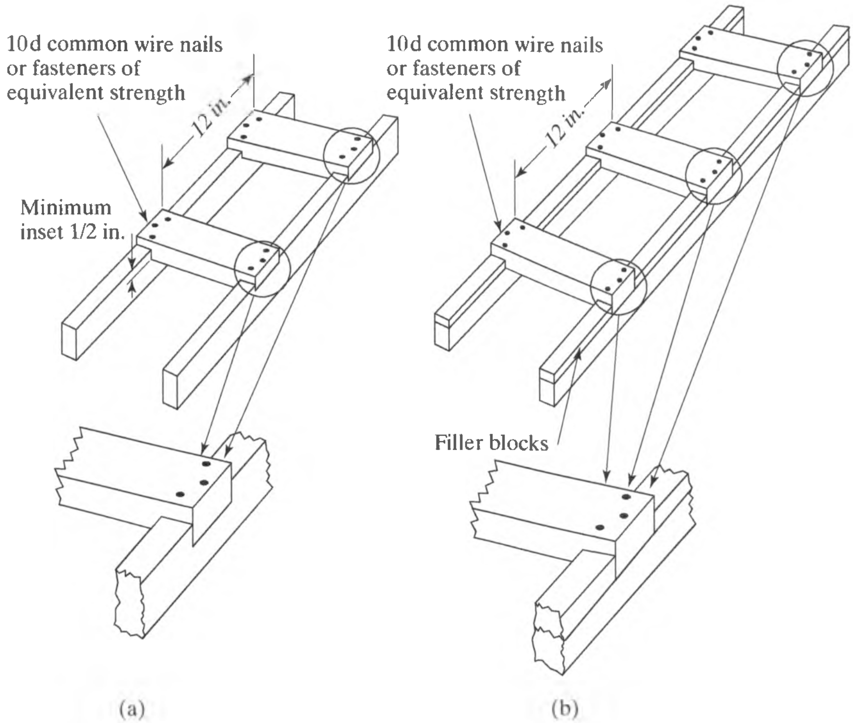


FIGURE 18.7

Two acceptable ways of setting cleats in construction job-made ladders: (a) cleats inset into side rails; (b) cleats braced by filler blocks.

scaffolds with unfamiliar names, such as "window-jack scaffolds," "outrigger scaffolds," and "chicken ladders," are rarely seen. The most popular scaffolds are the following types:

- Welded frame (or "bedstead" scaffolds)
- Manually propelled mobile scaffolds (on casters)
- Two-point suspension (or "swinging" scaffolds)
- Tube and coupler scaffolds

Some scaffolds, such as tube and coupler scaffolds and welded frame scaffolds, are supported by structure on the ground and must have sound footings. If the ground slopes, scaffold jacks may be necessary to assure that the footings are level. Certain engineered "cribbing" may be acceptable, but such unstable objects as barrels, boxes, loose brick, or concrete blocks are criticized. Concrete blocks are a real problem because most people feel that they are very strong and rigid. However, scaffolds direct very highly concentrated loads on their relatively tiny feet, and such loads can break through a molded concrete block. Once a scaffold support breaks through its footing, a major shift can occur aloft, and the consequences can be extremely serious. Such a mishap is most likely to occur at the worst time (such as when personnel are on the scaffold). In many cases, the danger is in the construction and disassembly of the scaffold as Case Study 18.1 will illustrate.

CASE STUDY 18.1

SCAFFOLD DISASSEMBLY ACCIDENT

On April 3, 2006, in downtown Boston, Massachusetts, a mast-climbing scaffold tipped over and two workers and scaffolding fell seven stories onto traffic. In addition to the worker fatalities, a passing motorist was killed by falling material. The accident happened as wall ties used to anchor the scaffold to the building were removed. Standard procedure when disassembling mast-climbing scaffolding is to secure the scaffold to a crane or other support device before removing the wall ties. The contractor was cited with 8 violations and total fines of $119,000 including a willful citation for improper removal of bracing.

The accident in Case Study 18.1 appears to have been preventable if standard procedure had been followed. OSHA representatives said, "Failure to follow proper dismantling procedures resulted in this accident and the ensuing deaths and injuries."

For scaffolds suspended from above, such as from two-point suspension (swinging) scaffolds, the security of the attachment on the roof is of obvious importance. Since rooftops vary in structure and design, an engineer is very useful in ensuring a safe anchor point. Cornice hooks are designed to hook over the edge, not into it. In addition, tiebacks are needed as a secondary means of support. Sometimes a sound structure for the tieback is not available on the rooftop, and the only solution is to cross the entire roof and go down to the ground on the other side of the building. Tying a scaffold to an ordinary vent pipe on the roof is asking for trouble.

Safety harnesses and lifelines for personnel on suspended swinging scaffolds must be tied to the building, not to the scaffold. Thus, if the scaffold falls, the personnel can still be saved. For guidance on the attachment of the lanyard to the lifeline, refer back to the earlier discussion of fall protection.

The floor of the scaffold is also important. Loose planks can be especially hazardous if the overhang beyond the support is insufficient for security. However, too much overhang can also be dangerous because a worker might step beyond the support and cause the plank to tip like a seesaw. Figure 18.8 illustrates minimums and maximums for plank overhang. Figure 18.9 illustrates the minimum for overlap, unless planks are secured from movement.

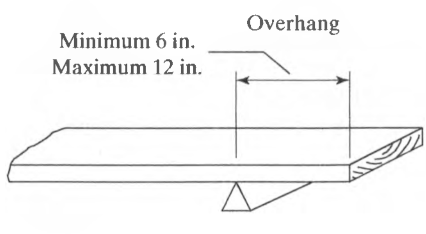


FIGURE 18.8

Scaffold plank overhang specifications.

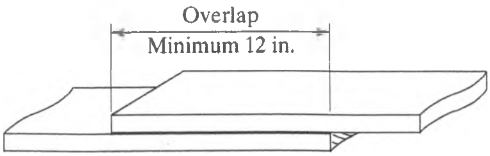


FIGURE 18.9
Scaffold plank overlap specifications.

FLOORS AND STAIRWAYS

As in general industry, the standard for guarding of open-sided floors and platforms is one of the most frequently cited standards in construction. Curiously, though, instead of setting the vertical fall distance at 4 feet as in general industry, the specification for construction is *6 feet.* Thus, an open-sided floor or platform 6 feet or more above the adjacent floor level is required to be guarded by a standard railing. Runways 4 feet high or more must be guarded.

During construction of buildings with stairways, construction employees use the new stairways during finishing operations for the building. If the building's stairways are properly designed (see Chapter 7), the safety and health manager for the construction company has little to worry about.

A pitfall needs mentioning on the subject of use of new building stairways during construction. Many stairways and landings today are of steel construction with hollow pan-type treads that are filled on-site with concrete or other materials. Contractors often save until last the job of pouring the treads. Meanwhile, during building construction, workers are walking on the unfilled treads and are subject to the trip hazard created by the steel nosing along the leading edge of the riser. Of course, exposure to the hazard is unavoidable during the actual construction of the stairway itself. However, after the stairways have been installed, lumber or other temporary material can be used to fill the hollow space and eliminate the trip hazard during completion of the building.

CRANES AND HOISTS

Cranes, hoists, and other material- or personnel-handling equipment are essential tools of the construction industry. Chapter 14 investigated the hazards of these machines in detail. This chapter discusses the subject from the viewpoint of the construction industry, the most important user of these machines.

One of the hazards addressed in Chapter 14 was two-blocking. Although two-blocking can be a hazard with any crane or hoist, most of the fatalities resulting from this hazard have occurred in the construction industry. A crane can be two-blocked in many ways. Hoisting the load, extending the boom, or even *lowering* the boom on a crane with a stationary winch mounted to the rear of the boom hinge can lead to two-blocking. It is difficult for the crane operator to avoid all of the ways in which a crane can be two-blocked, and consequently fatalities have occurred even when experienced crane operators are at the controls. In 1973, the ANSI standard[2] for mobile hydraulic cranes incorporated a requirement for a "two-blocking damage prevention feature" on telescoping boom cranes with less than 60 feet of extended boom. Safety and health

[2]ANSI B30.15–1973.

managers should beware of the temptation to purchase old equipment that might not be built to safe standards. And for equipment that has been purchased, the feasibility for retrofit should be considered.

On construction sites, the simultaneous execution of many parts of the overall project means that personnel will often be working around or near a crane in operation. The crane operator will avoid moving the bucket or other load over personnel and will attempt to keep the cab from striking personnel, but it is impossible for the crane operator to watch all moving parts at all times. Particularly hazardous is the rear of the cab, which on many models swings outside the crawler or other substructure when the cab and boom rotate. This motion generally occurs on every cycle of a crane's operation and is a constant threat to personnel on the ground. The hazard is a very serious one, and accidents carry a high likelihood of fatality. The employee may be either struck or crushed between the cab and some other object, such as a building wall, stack of materials, or another vehicle.

Another serious hazard with construction cranes is the possibility of contact with exposed live overhead utility lines. Crane boom contact with high-voltage transmission lines results in fatalities every year. The higher the voltage, the greater must be the clearance between the crane and the electric transmission line, to prevent arcing. Federal standards recognize this physical reality by setting up formulas for calculating the minimum clearance required for various voltages. Recognizing that during transit it may be more difficult to maintain clearances, OSHA standards are a little more lenient for cranes in transit. Further complicating the problem is that requirements for cranes in general industry are different from requirements in construction, resulting in a very complicated set of requirements. These requirements are summarized in Figure 18.10.

During operation of the crane, maintaining the required safe clearance distance as specified in Figure 18.10 demands considerable skill on the part of the crane operator.

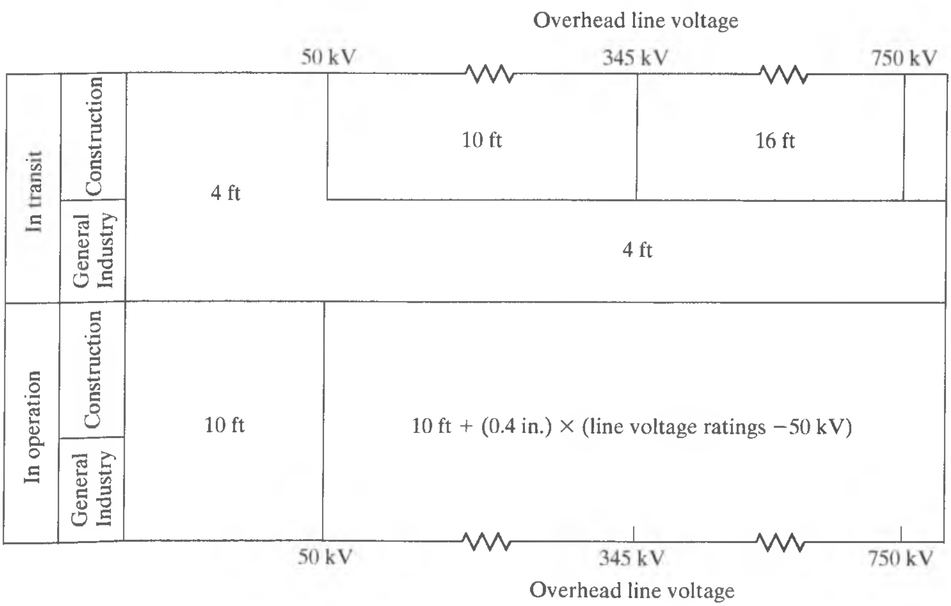


FIGURE 18.10

Clearance for cranes from electric transmission lines.

The operator must consider the possibility of a falling crane boom in the event of a mechanical malfunction of the crane during operation. Figure 18.11, Illustration A, reveals a way in which the safe clearance distance can be compromised during crane

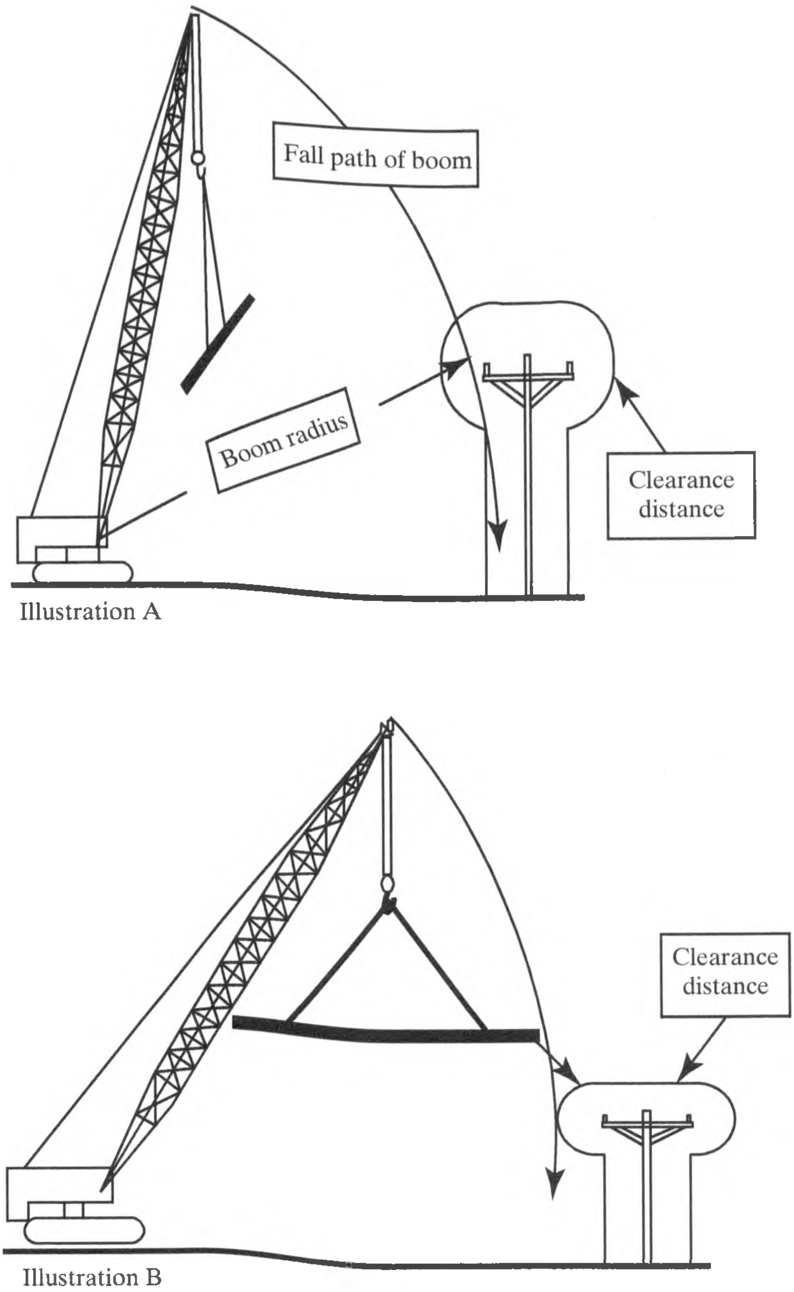


FIGURE 18.11

Crane operator skill is needed to avoid accidental violation of safe clearance distances during operation.

malfunction. Another way in which the safety clearance can be violated during actual operations is shown in Figure 18.11, Illustration B. In this situation, the load that is attached to the hook is seen to swing into the danger zone, even if the crane hardware itself stays clear.

A common worker practice is "riding the headache ball." Figure 18.12 identifies the headache ball as the ball-shaped weight used to keep a necessary tension on the wire rope when the hook is not loaded. It is possible for workers to stand on this ball and take a ride, using the crane as an elevator, a practice that usually horrifies passersby. Riding the headache ball is not explicitly addressed in the OSHA standards, but is generally considered a dangerous practice. OSHA can turn to the General Duty Clause to cite dangerous practices likely to cause death or serious physical harm. Also, lack of fall protection can be cited in cases where persons are riding the headache ball without fall protection. The practice is so highly visible to the public from the street that it easily can trigger an OSHA inspection. If persons are to be elevated using a crane, the recommended practice is to use a lift cage attached to the crane hook.

Hammerhead tower cranes are large structures that take advantage of counterweights on the end of the jib opposite the work (see Figure 18.13). This crane is often used for large building construction. Sometimes construction workers will have duties *on* the horizontal jib of a hammerhead tower crane. This presents a fatal fall hazard, and guardrails or safety harnesses, lanyards, and lifelines are needed to protect the worker.

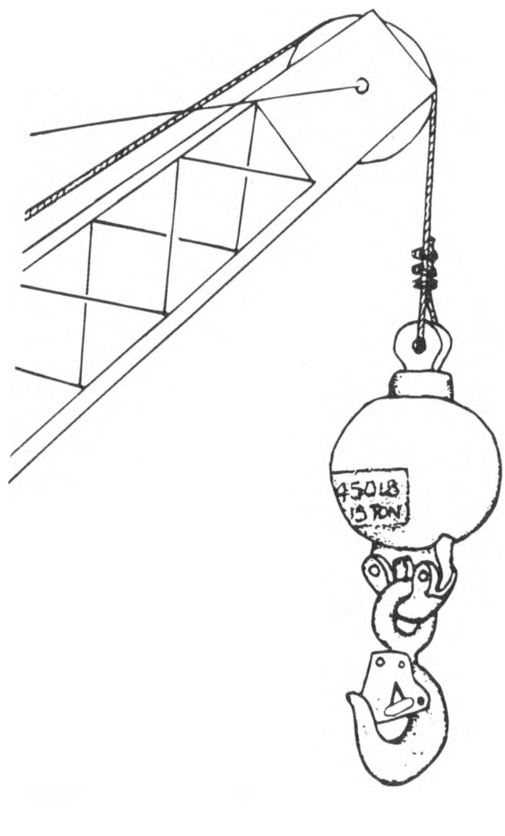


FIGURE 18.12

Headache ball. These balls range in weight from less than 100 pounds to 1 ton or more. The weight of the ball overcomes the friction of the sheaves for the running rope of the crane. The headache ball should not be confused with the much heavier wrecking ball.

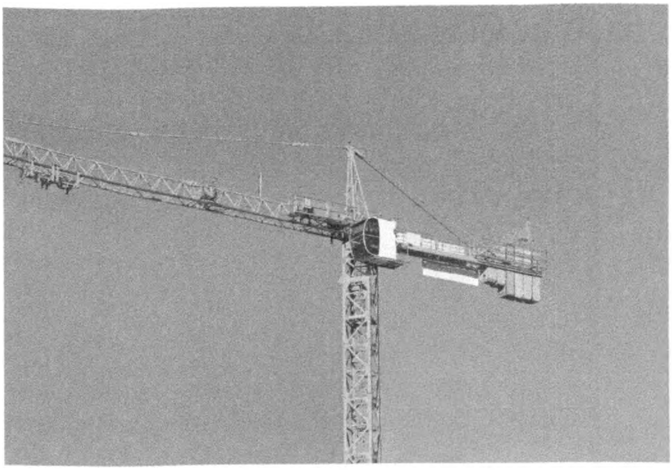


FIGURE 18.13
Hammerhead tower crane.

Public interest in construction crane hazards intensified in 2008 with several high-profile crane accidents in downtown areas, summarized as follows:

Location	Date	Number of Fatalities
New York	March 15, 2008	Seven
Miami	March 25, 2008	Two[a]
New York	May 30, 2008	Two

[a]One of the victims was a safety consultant.

In addition, a concrete collapse in January, 2008, in the construction of Donald Trump's hotel and condo project in New York caused a worker to fall 42 stories to his death.

Helicopters are sometimes used in construction for such operations as the placement of a steeple. Although the use of helicopters in construction is rare, the nature of the hazards of the operation is somewhat strange and therefore deserves some mention. Ordinary tag lines, used with all cranes to control the load from below, can be a hazard to helicopters because the lines can be drawn up into the rotors, resulting in a tragedy. Tag lines must be of a length that will not permit their being drawn up into the rotors.

Cargo hooks are another problem with helicopters used as cranes. With ordinary cranes, the sole concern is that the hook will hold and not release at the wrong time. With helicopters, there is this concern and the additional concern that the hook might *not* release at the right time. Cargo hooks for helicopter cranes need to have an emergency mechanical control to release the load in case the electrical release fails.

Another unusual effect that can represent a hazard is the generation of a static electrical charge on the load. This charge is developed by the friction of the air on the rotor and other moving parts. To deal with this hazard, a grounding device can be used to dissipate the charge before ground personnel touch the load, or protective rubber gloves can be worn. Once the load actually touches down, the static charge is generally dissipated through the load itself directly into the ground.

An indirect hazard that can develop from the use of helicopters is fire on the ground. The rotating blades generate such a wind on the ground that it is considered unsafe to have open fires in the path of a low-flying helicopter.

Material and Personnel Hoists

Temporary external elevators are often used on construction sites to move workers and materials and must be designed, maintained, and used properly to avoid a serious hazard. The seriousness of this hazard is quite personal to one of the authors of this book because his brother narrowly escaped a fatal accident on such a hoist when two of five members of his engineering inspection section were killed when a personnel hoist failed in an oil refinery. Two others were totally and permanently disabled, and the fifth, the author's brother, was uninjured because he had been asked to remain in the office that fateful day to complete an engineering drawing.

The design requirements for personnel hoists and material hoists are different, and one of the principal safety factors is maintaining the distinction between the two hoists during use. Material hoists must be conspicuously marked "No riders allowed." On the other hand, it is permissible to move material on a personnel hoist provided that rated capacities are not exceeded.

Latched gates are needed to guard the full width of the landing entrance for both material and personnel hoists. In the case of personnel hoists, an electrical interlock must not allow movement of the hoist when the door or gate is open. Furthermore, on personnel hoists, the hoistway doors or gates must have mechanical locks that are accessible only to persons in the car.

Aerial Lifts

An alternative to scaffolds, ladders, and hoists is needed for high and awkward locations on a construction site. The use of vehicle-mounted boom platforms or aerial "buckets" is becoming increasingly popular. The boom is usually *articulating* (capable of bending in the middle) or is *hydraulically extensible* (telescoping) or both.

The biggest problem with aerial lifts is not their construction, but the way they are used. Anyone in an aerial bucket needs to recognize the difference between his or her perch and terra firma. The floor of the bucket is the only place to stand—not on a ladder or plank carried aloft. Sitting on the bucket's edge is also dangerous. Even if the worker *does* stand properly in the bucket, a body harness with lanyard tied to the boom or bucket is needed to protect against a hazard such as a surprise encounter with a tree limb or a dip in terrain that can toss the operator from the basket.

HEAVY VEHICLES AND EQUIPMENT

Next to falls and electrocutions, more construction fatalities involve vehicles, tractors, and earthmoving equipment than any other hazard source. The fatality hazard is both to drivers of the equipment and to their coworkers. Vehicle *rollovers* are the principal cause of driver fatalities, whereas vehicle *runovers* are the problem for coworkers. Not to be excluded, however, is a significant number of fatalities from repairing tires for these vehicles.

ROPS

The acronym ROPS (rhymes with "hops") represents the term *rollover protective structures* and is a major change in construction vehicle design brought about by federal safety standards. The purpose of the ROPS, illustrated in Figure 18.14, is to protect the operator from serious injury or death in the event the vehicle rolls over. The following kinds of construction equipment require ROPS:

- Rubber-tired, self-propelled scrapers
- Rubber-tired, front-end loaders
- Rubber-tired dozers
- Wheel-type agricultural and industrial tractors
- Crawler tractors
- Crawler-type loaders
- Motor graders

Exempted are sideboom pipelaying tractors. To be effective, the ROPS system must be able to withstand tremendous shock loads, which increase as the weight of the vehicle increases. The standards are quite specific regarding the structural tests to which ROPS systems must be subjected in order to qualify. For all wheel-type agricultural and industrial tractors used in construction, either a laboratory test or a field test is required to determine whether performance requirements are met. The laboratory test may be either static or dynamic. In the static test, the stationary tractor chassis is gradually loaded while strain is measured by deflection instruments. The required input energy is a function of tractor weight, which in turn is required to be a function of tractor horsepower. In other words, the tractor's gross weight cannot be lightened below rated horsepower limits in order to meet ROPS tests.

The dynamic test, an alternative to the static test, uses a 2-ton pendulum that provides an impact load on the rear and side of the ROPS in successive tests. The height from which the pendulum is dropped is dependent on the calculated tractor weight based on horsepower, as in the static test just described. Deflection limits must not be exceeded.

If the field test is used, the tractor is actually rolled over, both rearward and sideways, as both types of accidents can easily occur. If the actual weight of the tractor is less than specified for its horsepower, ballast must be added for the tests.

For all ROPS tests, it is a good idea to remove protective glass and weather shields, which would probably be destroyed during the test. If there is any question whether

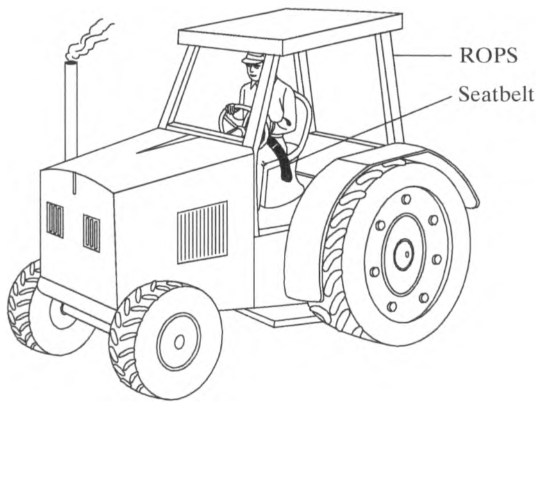


FIGURE 18.14

Rollover protective structures for construction vehicles prevent fatalities when used with seat belts.

such shields may absorb some of the energy, thereby assisting ROPS to pass the test, the shields *must* be removed.

Having read thus far, one can see that retrofitting an old tractor to meet current requirements for ROPS is not an easy task. The safety and health manager is cautioned against taking the tractor to a local welder and requesting a ROPS system to be fabricated. Unless the tractor is actually going to be subjected to the standard ROPS test, the frame should be of a design identical to a frame actually tested for the model tractor in question. Very old or rare model tractors are obviously a problem. If a qualified ROPS system is removed for any reason, it must be remounted with bolts or welding of equal or better quality than those required for the original. The ROPS must be permanently labeled with manufacturer's or fabricator's name and address and the machine make, model, or series number that the structure is designed to fit. This labeling requirement is a sobering thought for the welder or fabricator who is asked to retrofit an old tractor with an ROPS system. All told, it is easy to see why most companies dump the old equipment on the used-equipment market, and many are shipped to foreign countries that do not require ROPS.

After the safety and health manager has ensured that all appropriate construction equipment has been equipped with ROPS systems, the next task is to ensure that the equipment is used properly. Essential to the effectiveness of the ROPS system is that the operator wear a seat belt. If the operator is thrown out of the vehicle, the ROPS will afford no protection at all and may actually contribute to a fatality. Passengers are another hazard unless the vehicle is equipped with seat belts for passengers. Hitchhiking on heavy equipment at construction sites is a dangerous practice.

Runover Protection

Most of the balance of fatalities with heavy construction equipment is due to personnel being run over by the equipment. Confrontation of this major fatality category has two main thrusts: operator visibility and pedestrian awareness.

Operator visibility as good as the visibility in a private automobile is simply not feasible for a huge piece of earthmoving machinery. It is no wonder that runovers occur frequently on construction sites. The operator needs all the help affordable, but ironically, some of the poorest windshield conditions occur on construction equipment. In the morning, the operator, foreperson, and everyone concerned is anxious to get equipment rolling, but if the morning is cold, defrosting and defogging are essential. Often, the defrosting or defogging equipment is ineffective. Dirty or cracked windshields are also a common sight in the harsh environment of the construction job.

The second link in the hazard-prevention chain for runovers is the horn used by the operator to warn personnel when visibility *is* good enough to notice the endangered worker on the ground. Personnel are generally distributed all over a construction site, and the operator needs a good operable horn to warn them when they are dangerously close.

Besides the ordinary horn, many construction vehicles also need "backup alarms." Earthmoving equipment and construction vehicles that have an obstructed view to the rear need these backup alarms if they are used in reverse gear. The term *obstructed view* may be somewhat vague, but most safety and health professionals are taking the position that earthmoving machines of all types need these backup alarms. Too many people have been killed by machines backing over them to take this requirement lightly. This is said although it is acknowledged that the steady beep-beep-beep of the backup alarms can be very monotonous on a construction site and perhaps even lead to a certain complacency on the part of the personnel endangered. An alternative to the beeping backup alarms is the use of an observer standing behind the machine to alert others every time the machine backs up. This is expensive, though, and has the disadvantage of being an *administrative* or *work-practice control*, instead of the preferred *engineering control* represented by the backup alarm.

Dump Trucks

One more hazard with construction vehicles and equipment needs emphasis. Dump trucks can cause a terrible accident if the raised dump body falls while the driver or some other worker has crawled into the exposed area for maintenance or inspection work. Sometimes all that holds the dump body aloft is the pressure in a hydraulic line, which can be suddenly lost due to any of a variety of failure modes. For this reason, the safety of the maintenance or inspection worker inside the exposed area demands that the truck be equipped with some positive means of support, permanently attached and capable of being locked into position.

TRENCHING AND EXCAVATIONS

A major cause of construction fatalities is the sudden collapse of the wall of a trench or excavation. It is difficult to imagine the drama of digging for a coworker who has been literally buried alive in such a cave-in. Before becoming involved in the field of occupational safety and health, one of the authors of this book coincidentally became an eyewitness to such a drama in Tempe, Arizona. The trench was located directly below a public stairway landing on which the author happened to be standing, and thus his vantage point was directly over the scene of the cave-in. The impression was unforgettable, and its memory would motivate anyone to try to prevent such accidents in the future, a point supporting the principles of hazard avoidance set forth in Chapter 3. Recognizing the seriousness of this hazard, OSHA has undertaken several special-emphasis programs on trenching and excavation cave-ins. Joseph Dear (1995), in the mid-1990s, cited a dramatic result of such emphasis in the state of Indiana where trenching and excavation fatalities decreased from six per year to one per year after conducting special trenching programs. Despite special emphasis on this dramatic hazard, the problem continues in the twenty-first century, with OSHA reporting in late 2016 that trench deaths more than doubled in the year 2016 over the year 2015 (Ohio worker's death highlights grim 2016 national stat: trench collapse fatalities have more than doubled, 2016).

All trenches are excavations, but not all excavations are trenches. Trenches are narrow, deep excavations; the depth is greater than the width, but the width is no greater than 15 feet, according to the standard definition. A trench is more confined and generally more dangerous than other excavations, especially because both walls can collapse, trapping the worker. However, the walls of a trench are easier to shore than the walls of an excavation. Both are dangerous if over 5 feet deep and will easily snuff out the life of anyone who stands in the path of a collapsing wall. The hazard is not simply one of suffocation. A cave-in generally represents tons of falling earth, which can crush the body and lungs of the worker even if the face and breathing passages are left clear.

The *angle of repose* is defined as the greatest angle above the horizontal plane at which a material will lie without sliding. The angle naturally varies with the material, and approximate angles are shown in Figure 18.15. The science of soil slides is not exact, and the uncertainty thwarts attempts to control the hazard. It is difficult to say whether a particular soil type is "typical" or "compacted angular gravels," or something between the two. The specifications for trench shoring are more detailed, as can be seen in Table 18.2.

Adding to the uncertainty of the cave-in hazard are certain hazard-increasing factors, such as the following:

- Rainstorms, which soften the earth and promote slides
- Vibrations from heavy equipment or street traffic nearby
- Previous disturbances of the soil, as from previous construction or other excavations
- Alternate freezing and thawing of the soil
- Large static loads, as from nearby building foundations or stacked material

Although judgment is required in deciding whether to employ shoring, the hazard is so serious that it is wise to adopt a conservative policy, well clear of the marginal area where a cave-in might or might not occur. One thing is certain: *After* the cave-in *does* occur, and there is a fatality, the OSHA officer will come to the scene, and everyone (including the OSHA officer) will conclude that the shoring or cave-in protection was insufficient.

A trench shoring system is shown in Figure 18.16. The trench jacks may be either screw type or hydraulically operated. They need to be secured to prevent falling or sliding if they loosen as the sidewalls adjust slightly. Care must be taken to level the jacks and also to be sure that they are below the plane of the surface of the surrounding earth. A trench jack placed too high can be subjected to bending stresses, as shown in Figure 18.17. This can damage or even ruin the trench jack. The shoring system should be removed slowly and carefully. It is sometimes necessary to remove braces or jacks by means of ropes from above after everyone has cleared the trench.

A cave-in is not the only hazard to working in trenches and excavations. All workers in the ditch are subject to the hazards of falling rocks, tools, timbers, or pipes. Head protection is needed for workers below, and good housekeeping is important along the edges of the excavation.

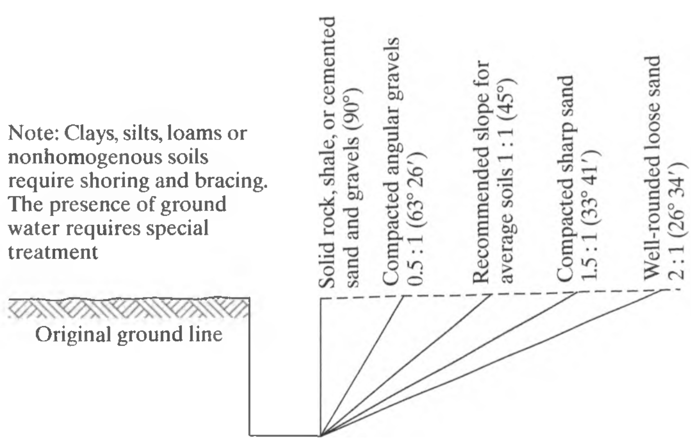


FIGURE 18.15

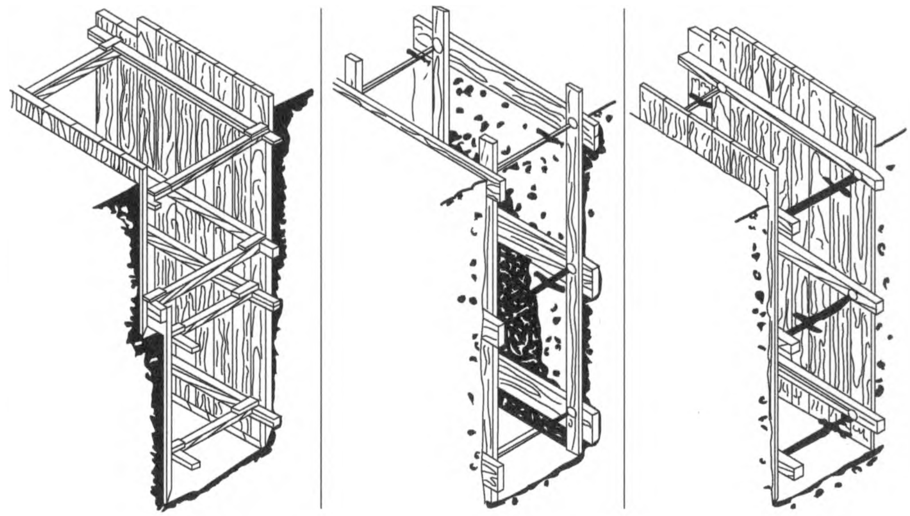
Approximate angle of repose for sloping the sides of excavations.

TABLE 18.2 Trench Shoring—Minimum Requirements

Depth of trench (feet)	Kind or condition of earth	Uprights: Minimum dimension (inches)	Uprights: Maximum spacing (feet)	Stringers: Minimum dimension (inches)	Stringers: Maximum spacing (feet)	Cross braces[a] (inches), Width of trench (feet): Up to 3	3–6	6–9	9–12	12–15	Maximum spacing (ft): Vertical	Horizontal
5–10	Hard, compact	3 × 4 or 2 × 6	6			2 × 6	4 × 4	4 × 6	6 × 6	6 × 8	4	6
	Likely to crack	3 × 4 or 2 × 6	3	4 × 6	4	2 × 6	4 × 4	4 × 6	6 × 6	6 × 8	4	6
	Soft, sandy, or filled	3 × 4 or 2 × 6	Close sheeting	4 × 6	4	4 × 4	4 × 6	6 × 6	6 × 8	8 × 8	4	6
	Hydrostatic pressure	3 × 4 or 2 × 6	Close sheeting	6 × 8	4	4 × 4	4 × 6	6 × 6	6 × 8	8 × 8	4	6
10–15	Hard	3 × 4 or 2 × 6	4	4 × 6	4	4 × 4	4 × 6	6 × 6	6 × 8	8 × 8	4	6
	Likely to crack	3 × 4 or 2 × 6	2	4 × 6	4	4 × 4	4 × 6	6 × 6	6 × 8	8 × 8		6
	Soft, sandy, or filled	3 × 4 or 2 × 6	Close sheeting	4 × 6	4	4 × 6	6 × 6	6 × 8	8 × 8	8 × 10	4	6
	Hydrostatic pressure	3 × 6	Close sheeting	8 × 10	4	4 × 6	6 × 6	6 × 8	8 × 8	8 × 10	4	6
15–20	All kinds of conditions	3 × 6	Close sheeting	4 × 12	4	4 × 12	6 × 8	8 × 8	8 × 10	10 × 10	4	6
Over 20	All kinds of conditions	3 × 6	Close sheeting	6 × 8	4	4 × 12	8 × 8	8 × 10	10 × 10	10 × 12	4	6

[a]Trench jacks may be used in lieu of, or in combination with, cross braces. Shoring is not required in solid rock, hard shale, or hard slag. Where desirable, steel sheet piling and bracing of equal strength may be substituted for wood.

Source: Code of Federal Regulations 29 CFR 1926.652.



(a) (b) (c)

FIGURE 18.16

Trench shoring system: (a) bracing used with two lengths of sheet piling; (b) bracing with screw jacks, hard soil; (c) screw jacks used with complete sheet piling
(*Source*: Courtesy of the National Safety Council, Chicago; used with permission).

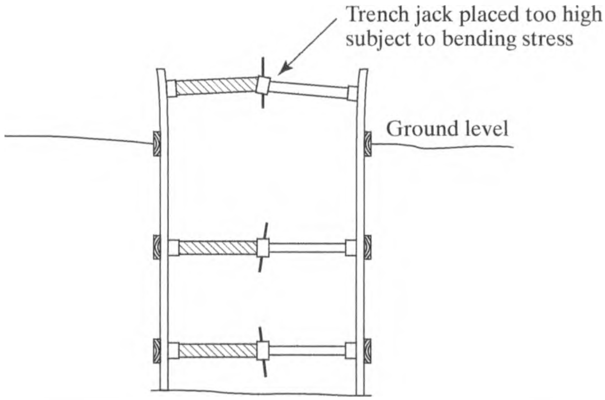


FIGURE 18.17

Improperly placed trench jack.

Even when personnel are not inside the excavation and machines do all the work, another hazard presents itself. Utility lines are often broken, resulting in fire, explosion, or inhalation hazards. Such accidents are not only dangerous, but also always costly and require additional coordination with the utility company—coordination that would have been better handled in advance of the excavation. The safety and health manager should install a procedure that ensures that someone stops and checks with utility companies before proceeding "blind" into an excavation project. Excavation contractors are generally familiar with the information system for dye marking underground utilities. Signs often post warnings: "DO NOT DIG; BURIED UTILITIES." Most communities have a toll-free number accessing a free service for dye marking underground utilities to warn excavation contractors before proceeding.

Signs of an imminent cave-in, rupture of a utility line, dangerous accumulations of toxic gases in deep excavations, or other possible emergency situations dictate the need for quick and easy exit. A ladder, steps, or other adequate means of exit should be located so as to require no more than 25 feet of lateral travel for escape.

It was stated at the beginning of this section that OSHA has undertaken several "special-emphasis" programs for enforcement of trenching and excavation hazards. Just how much "special emphasis" does OSHA place on this type of hazard? Some insight is provided in a 1997 news release (Fleming, 1997) in which OSHA stated that in the previous 5-year period the agency and state agencies having enforcement jurisdiction had conducted a total of 9400 trenching inspections. Of these, almost 200 inspections were investigations of fatal accidents. Trenching and excavations remain as one of the principal hazards of the construction industry, and it is likely that OSHA will continue its emphasis well into the twenty-first century.

CONCRETE WORK

Perhaps the most dramatic industrial accident in history involved concrete work and is described in Case Study 18.2.

CASE STUDY 18.2

WILLOW ISLAND NUCLEAR TOWER COLLAPSE

In 1978, in Willow Island, West Virginia, a huge cooling tower for a nuclear power plant was under construction. The continuously poured concrete walls of the structure supported scaffolds for workers 170 feet above the ground. At the time of the accident, the "green" concrete wall was insufficiently cured to accept the load. The wall failed, dropping the scaffold; 51 workers fell to their deaths.

The pressure to keep a construction project on schedule is antagonistic to the careful curing of concrete. However, the consequences of rushing the job are serious even if no one is injured. The memory of the tragic Willow Island accident serves to remind concrete project managers of these consequences. Concrete curing time is a function of both time and temperature. About 70°F is ideal, and temperatures either too hot or too cold can delay curing.

Even before the concrete is poured there are hazards to the placement of the reinforcing steel *rebars*. For vertical structures, rebars need guys or other support to prevent collapse. Another hazard is the protruding points of exposed vertical rebars. It may seem farfetched, but workers have actually been *impaled* by falling on these bars. The most serious hazards are for workers on ladders when these ladders are placed over

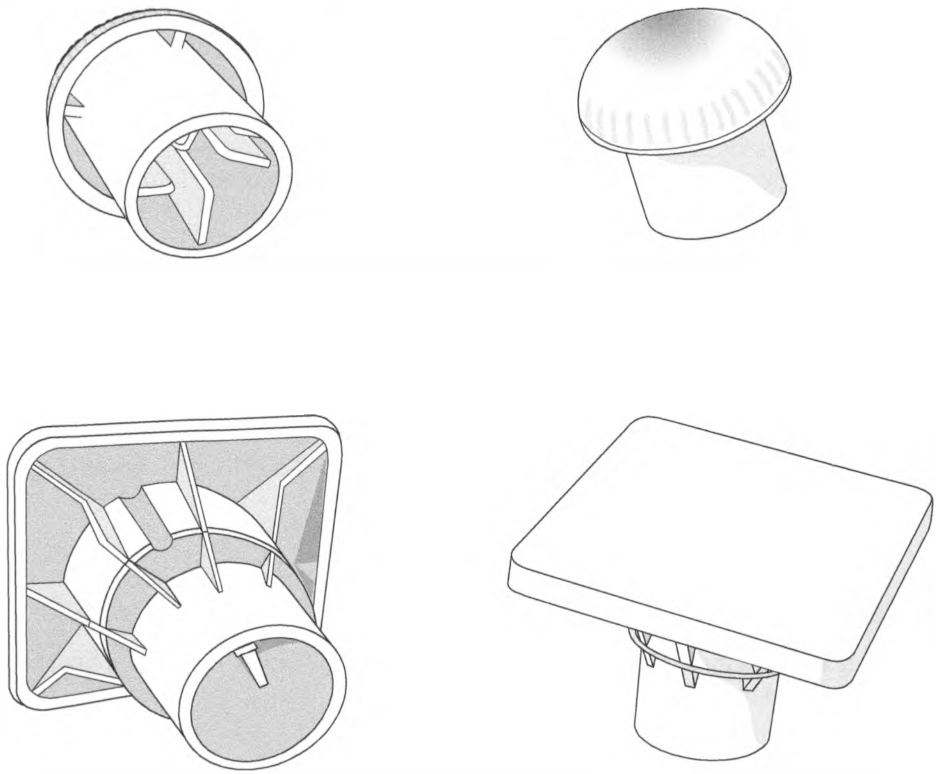


FIGURE 18.18

Two familiar models of concrete rebar caps to mitigate impalement hazards.

protruding rebars. However, even at floor or ground level, a trip and fall on an exposed rebar can be fatal. In one case, a worker stumbled at ground level and fell on an exposed rebar, which impaled his neck and ruptured his jugular vein. The life of the worker was saved by the quick action of a trained first-aid person. The answer to the exposed rebar problem is to bend down the ends, cover them with plywood, or wrap them with canvas until ready for pouring. Another solution, devised by an enterprising inventor, is a plastic cap that can be fitted on the top of the exposed end of the rebar. The cap, which is designed to be used on rebar of various diameters, effectively neutralizes the impalement hazard. The caps can easily be removed and used over and over, spreading out the cost over many construction projects. Figure 18.18 exhibits two familiar models of the rebar caps.

Concrete forms need carefully designed shoring systems to prevent collapse together with hazards reminiscent of the excavation cave-in hazards discussed earlier. The hydrostatic pressure of wet concrete can be very great just after it is poured. Then, at a time when the forms' stress is greatest, vibrating equipment is often applied to ensure even distribution, adding to the stresses on the forms. Overdesign is necessary to prevent the hazard of forms "kickout." Proper concrete form design is essential to ensure the safety of personnel. Case Study 18.3 illustrates the dangers of improper shoring.

CASE STUDY 18.3

CONCRETE SHORING FAILURE

On July 5, 2007, the shoring on a partially poured concrete floor collapsed during the construction of a condominium in Denver, Colorado. The collapse dumped concrete and workers from the 14th story to the 13th story. Thirteen people were injured, several seriously. OSHA proposed fines of $166,000 citing willful, unsafe working conditions (Concrete Collapse, 2008).

Concrete is often poured by buckets handled by cranes. Unfortunately, vibrator crews have to work with the freshly poured concrete in close proximity to the moving bucket. The pouring strategy should be to keep the vibrator crews away from the overhead path of the bucket. Riding the concrete bucket is prohibited.

STEEL ERECTION

Who has not marveled at the daring of the high-rise steelworker "walking the beam" hundreds of feet up the steel superstructure of a new building under construction? Perhaps this work will always be dangerous, but the hazard has been mollified somewhat by requiring safety nets to be installed whenever the fall distance exceeds two stories or 25 feet. An alternative is to use scaffolds or temporary floors. Case Study 18.4 is a classic example of the benefits of using safety nets in steel erection.

CASE STUDY 18.4

SAFETY NETS ON THE GOLDEN GATE BRIDGE

The construction of San Francisco's Golden Gate Bridge in the 1930s was a dramatic engineering feat made even more perilous by the wind, rain, and ocean tides. Many workers lost their lives due to falls into the treacherous water. After the death toll reached 23, workers refused to continue without increased safety protection. Work was resumed after safety nets were installed. An additional 10 workers fell from the bridge, but all 10 were saved by the safety nets (Avers, 1993).

A safety railing around the perimeters of temporary floors is now required for tier buildings and other multifloored structures. During structural steel assembly, however, the use of $\frac{1}{2}$-inch wire rope approximately 42 inches high is permitted for the safety railing. To be effective, the wire rope should be checked frequently to be sure that it remains taut.

To maintain structural integrity on the way up, the permanent floors should follow the structural steel as the work progresses. The general rule is no more than eight stories between the erection floor and the uppermost permanent floor. No more than four floors or 48 feet of unfinished bolting or welding is permitted above the foundation or uppermost permanently secured floor.

Structural steel erection sites are subject to constant hazards of falling objects. Rivets, bolts, and drift pins are required to be stored in secured containers, and if all else fails, there is the hard hat to protect the worker below. For some objects at the steel erection site, the hard hat is no protection, however. One of the authors of this book was in Chicago for a safety meeting in the 1980s when a startling accident occurred during steel erection of a towering office building. A steel beam fell to street level and flattened a parked car from left taillight to right headlight. The author walked along the sidewalk from his hotel to the meeting in the morning before the accident occurred. A few hours later, in the afternoon, he walked back to the hotel along the same sidewalk and witnessed the smashed car, which was a total loss. The accident occurred during the meeting; luckily, no one was injured.

DEMOLITION

Some would say that the subject of demolition does not belong in this chapter, but demolition and construction are actually closely related. If the construction site is not clear, demolition of previous structures may be the first step in construction of a new building. Many of the tools and equipment, such as cranes and bulldozers, are the same.

People identify skill, knowledge, and quality as important to construction jobs, but most people do not think of demolition as requiring skill and knowledge. However, often the engineering expertise required of a demolition job far exceeds that required for the original construction. Buildings to be demolished have often been previously damaged by fire or may have been condemned for some serious reason, such as structural damage. Required for every demolition operation is a written report of an engineering survey conducted in advance.

A demolition operation begins with manual operations, such as disassembly of salvage items, and then proceeds to material teardown and dumping to street level. Dangers exist in the debris dumping operation. The area below needs protection if it is outside the walls of the structure. Well-designed chutes capable of withstanding impact loads, together with substantial discharge gates, are needed to control the dropping material. One hazard is that personnel can fall down the chute while dumping debris. A substantial guardrail about 42 inches high is needed to protect against this hazard. A toeboard or bumper is also needed, if wheelbarrows are used, to prevent losing the wheelbarrow down the chute.

Once light teardown operations are completed, heavier demolition equipment such as cranes with wrecking balls are used. Most walls are unstable without lateral support, so they should not be allowed to stand alone at heights greater than one story. No unstable standing wall should be left at the end of a shift.

One sensational demolition technique that is gaining in popularity is controlled explosive demolition, illustrated in Figure 18.19. In this method, carefully engineered explosive charges are detonated to precipitate a catastrophic failure of the building structure, resulting in an immediate and total collapse. The operation has been carried out successfully on many downtown buildings in U.S. cities, typically triggered at the

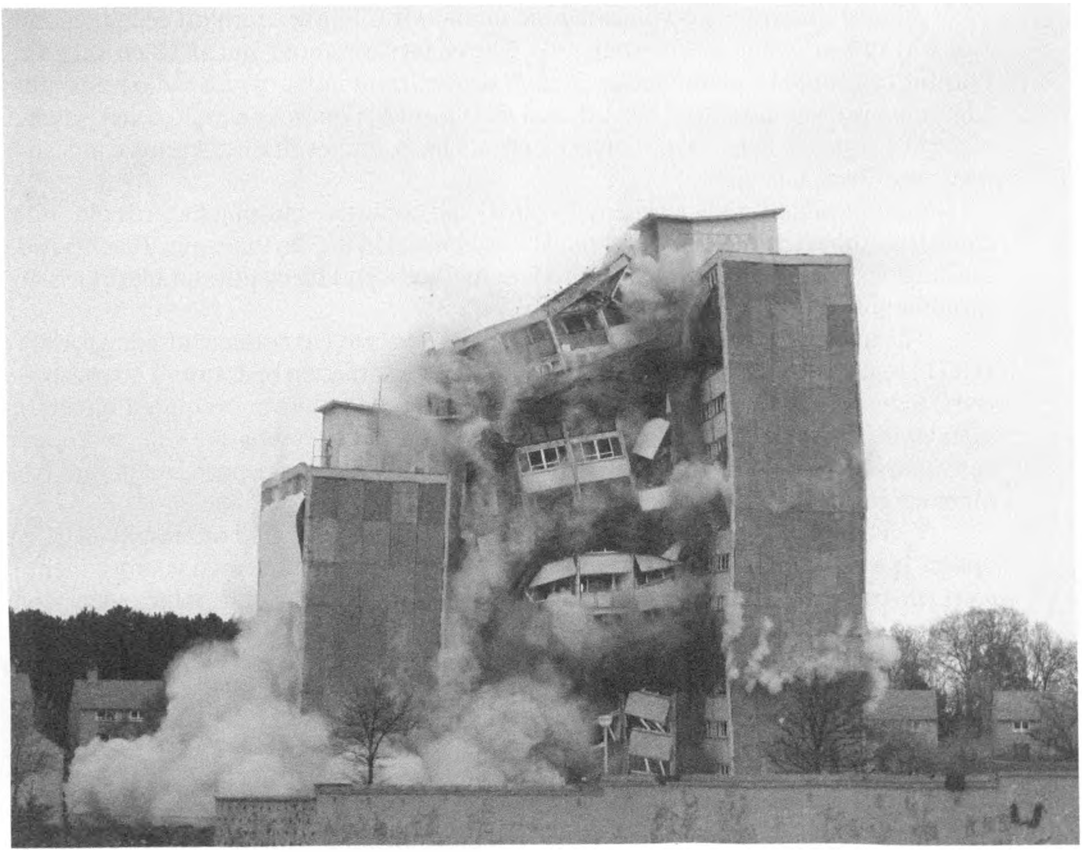


FIGURE 18.19

Building collapses under controlled explosive demolition.

quiet time of dawn on Sunday mornings. Although the operation is dramatic and seems dangerous, it is really quite safe and avoids many of the hazards of a slow tear-down process.

EXPLOSIVE BLASTING

Demolition is only one application for blasting; the construction industry has others. The preparation of roadway cuts is the most important. The chief concern with construction blasting is the safe handling, storage, and transportation of the explosives themselves. The reader might want to review some of the concepts of explosives handling covered in Chapter 11.

Almost everyone has witnessed the familiar warning to "turn off cell phones and two-way radios" when in a blasting area. The chance is remote, but an electrically fired blasting cap could be detonated by a small stray current induced by a radio transmitter. Lightning is even more of a hazard, and all blasting operations should cease when an electrical storm is near. Radar, nearby power lines, and even dust storms can also be sources of stray currents.

Good visibility reduces many hazards, and explosive blasting hazards are in this category. Aboveground blasting should be conducted in the daytime only. Black powder blasting has been replaced by safer modern methods, and black powder blasting is now prohibited in construction.

The transportation of explosive materials is subject to Department of Transportation (DOT) regulations familiar to suppliers and most construction operators who use explosives. Signs saying EXPLOSIVES in large (4-inch) red letters are required on all four sides of the vehicle. Blasting caps should be transported in a separate vehicle from the vehicle transporting other explosives, and both should be transported separate from other cargoes.

Vehicles for explosives need a good fire extinguisher rated at least 10-ABC on board. It would be foolhardy to attempt to control a fire in the cargo compartment of a vehicle transporting explosives. However, most vehicle fires begin in the engine compartment or outside but adjacent to the vehicle. Such fires can sometimes be controlled with a good fire extinguisher wielded by a trained operator, thereby averting a major explosives catastrophe.

ELECTRIC UTILITIES

A specialized type of construction is the erection and modification of electric transmission and distribution lines and equipment. The efficient transmission of usable levels of electrical power necessitates very high voltages. The rules for handling high voltages are quite different from the rules for handling ordinary household and industrial and commercial voltages. For instance, with ordinary voltages, a danger is the contact with exposed live parts. With high voltages, it can be dangerous even to approach the *vicinity* of live parts, as is reflected in Table 18.3 based on the OSHA standard. For voltages in the kilovolt range, the atmosphere may not be an effective insulator, and arcing becomes a hazard. Therefore, safety distances must be maintained. Of course, the distances shown in Table 18.3 apply safety factors. The actual physical arcing distances are much smaller, but there is an element of uncertainty due to such factors as humidity and barometric pressure. Furthermore, the electric-utility lineman may not be able to estimate precisely his distance from the high-voltage line or equipment, making safety factors essential.

Personal protective equipment for high-voltage work takes on a new dimension, that of *degree* of protection. Ordinary insulators on tools, protective gloves, and other insulating equipment that are effective insulators for ordinary applications might completely break down in high-voltage exposures. The whole business of working with energized high-voltage lines is a strange world to the uninitiated—a world fraught with curious physical effects. The electric-utility industry offers a prime example of an

TABLE 18.3 Minimum Clearance Distances for Live-Line Bare-Hand Work (Alternating Current)

	Distance (feet and inches) for maximum voltage	
Voltage range (phase to phase) (kV)	Phase to ground	Phase to phase
2.1–15	2–0	2–0
15.1–35	2–4	2–4
35.1–46	2–6	2–6
46.1–72.5	3–0	3–0
72.6–121	3–4	4–6
138–45	3–6	5–0
161–169	3–8	5–6
230–242	5–0	8–4
345–362	7–0[a]	13–4[a]
500–552	11–0[a]	20–0[a]
700–765	15–0[a]	31–0[a]

[a]For 345–362, 500–552, and 700–765 kV, the minimum clearance distance may be reduced provided that the distances are not made less than the shortest distance between the energized part and a grounded surface.
Source: Code of Federal Regulations 29 CFR 1926.955.

industry in which training in awareness and understanding of hazards is the key to a safe workplace, echoing the principles set forth in Chapter 3.

SUMMARY

The construction industry deserves special consideration because it is so dangerous and also because OSHA has watched construction more closely than general industries. The safety and health manager for construction jobs should remember that the principal task is to avoid *fatalities*. The top five categories of fatalities in the construction industry are

- Falls
- Electrocutions
- Vehicle rollover
- Personnel runover by vehicle
- Excavation cave-ins

It should be no surprise to the reader that "falls" appears at the top of the above list. Indeed, OSHA reported in a 2016 News Release that nearly 40 percent of all construction fatalities were the result of a preventable fall (Five companies face OSHA violations, $115K in fines after federal inspectors observe multiple safety hazards at Lincoln construction site, 2016)!

If the safety and health manager keeps all five of these fatality categories in mind, it will help to place overall efforts in proper perspective on the construction site.

This chapter is, to some extent, a summary of the entire book. The construction industry displays virtually every hazard presented by general industry, but in construction, the hazard is usually worse. Compounding the problem is the transitory nature of the problems that are encountered. It is difficult to pursue costly safeguarding procedures such as trench shoring when the exposure to the hazard will consist of only a few days or even hours. Construction schedules are always demanding for several reasons. High-stakes investments are on the line, costly interruptions to facilities and street traffic are often present, and unplanned chance events are always popping up to ensure that the construction project manager will always struggle to stay on schedule. In this environment, there will always be room for improvements to the safety and health program. What is true for construction is also true of general industry, although perhaps to a lesser degree. The reader should recognize the challenge that this reality represents.

It is hoped that this book has cast some light on the challenges that a safety and health manager faces in today's industrial and regulatory environment and some insights for dealing with these challenges. The field is certain to present new challenges in the coming years. Each new challenge ushers in new opportunities for safety and health managers to have an impact on the lives of their coworkers and on the health and financial well-being of their companies.

EXERCISES AND STUDY QUESTIONS

18.1 What is the minimum illumination level permitted for general construction areas? In what areas may lighting be reduced to 3 footcandles?

18.2 How are lasers used in construction?

18.3 What tensile strength is specified for safety belt hardware? Give two reasons that the specification is so much higher than the weight of any human being.

18.4 What is a safety belt lanyard? What nominal breaking strength is specified for lanyards?

18.5 What is a triple rolling hitch?

18.6 Compare hydraulic versus pneumatic power tools from a safety and health standpoint.

18.7 How are construction cranes particularly hazardous to persons on the ground?

18.8 Why are helicopter hooks (for load attachment) more complicated than those for ordinary construction cranes?

18.9 What does the acronym *ROPS* represent?

18.10 What are the two principal strategies for preventing personnel from being run over by construction equipment?

18.11 What is the difference between a trench and an excavation?

18.12 How can trench jacks be damaged by improper placements?

18.13 What is a rebar? Why is it dangerous?

18.14 When must steel erection workers be protected against falls with safety nets?

18.15 What type of safety rail construction is permitted during steel erection?

18.16 Why is an engineering survey required prior to demolition of a building?

18.17 Is it a good idea to carry a fire extinguisher aboard a truck that transports explosives? Why or why not?

18.18 A crawler-type construction crane is operating near a 550-kilovolt power line. What is the minimum distance the boom should approach the line?

18.19 The crawler-type construction crane in Exercise 18.18 finishes its job and travels to the next job, passing under the same 550-kilovolt power line where the power line crosses over a city street at a different location in the neighborhood. What minimum distance is specified for this situation?

18.20 Suppose in Exercise 18.18 that the crawler crane had been employed in general industry instead of construction. What minimum distance would be permitted in general industry?

18.21 For the crane of Exercise 18.20, what is the minimum clearance from the 550-kilovolt power line if the crane is in transit?

18.22 A painter is standing on a work platform that is 27 feet above ground level. For fall protection, the worker's safety harness is attached to a 12-foot safety line, which serves as a lanyard and is securely fastened to the structure at a point 40 feet above ground level. Does this arrangement violate standards for fall protection? Explain.

18.23 A convenient and secure attachment point for fall protection lines is located 35 feet above ground level on the exterior wall of a building. A 20-foot safety line, which can be used as a lanyard, is available for connection to this attachment point. What is the lowest and highest level at which a work platform can be safely positioned for workers to be protected by a 20-foot lanyard fastened to this attachment point? State any assumptions necessary to your solution.

18.24 Explain the hazard of mushroomed heads on chisels.

18.25 What provisions are specified by federal standards to protect workers from drowning?

18.26 Explain the coding system for identifying the power level for cased power loads for powder-actuated tools.

18.27 To comply with standards, how often should material handling rigging on a construction site be checked?

18.28 What is the standard method of disposing of scrap materials from higher than ground level during construction? What special precaution is required when the material to be discarded is at a height greater than 20 feet?

18.29 What is the principal fire hazard on construction sites?

18.30 What personnel hazard arises when a pneumatic power hose is severed? What device is specified by federal standards to deal with this hazard? What problems have been encountered in the field with the use of this device?

18.31 Describe several ways in which a crane can be maneuvered into a two-blocking situation. Prove your point using diagrams to clarify your reasoning.

18.32 What hazard takes priority in the selection of the type of hydraulic fluid to be used for general construction tools? How does this priority change when the hydraulic tools are used in the public-utility industry?

18.33 Compare the hazards of handguns and powder-actuated tools.

18.34 Explain the controversy behind the requirement for GFCIs in the construction industry.

18.35 What is a cornice hook? What additional precautions are needed when cornice hooks are used?

18.36 What is the principal hazard of using concrete blocks for scaffold "cribbing"?

18.37 What are hollow, pan-type treads, and what hazard do they represent? What can be done to alleviate this hazard during construction?

18.38 **Case Study.** A construction crane is resting with no load, and the headache ball is close to, but not touching, the nose of the crane boom, which is in an almost erect position. The running rope of the crane is mounted on a stationary winch to the rear of the boom hinge. While the operator is in the process of lowering the boom, the wire rope breaks and the headache ball and hook assembly falls to the ground. Explain the most likely cause of this accident. Use a diagram to show how the hazard would develop. What precaution could have prevented it?

18.39 How many lives were lost due to falls during the construction of the Golden Gate Bridge? How many additional falls occurred after the erection of safety nets? How many of these additional falls were fatalities?

18.40 At what time in a building's life is the floor likely to be subjected to its heaviest load?

18.41 What is "two-blocking," and under what conditions do ANSI standards require "two-blocking damage prevention features?"

18.42 How often must rigging for construction material handling be inspected for damage or wear?

18.43 What characteristic of artificial fiber ropes besides strength and weight make them especially favorable for selection as lanyard ropes?

18.44 What is "spalling" and what has it to do with the need for eye protection?

18.45 Is it okay to splice flexible extension cords on construction sites? Explain.

18.46 What is a "headache ball" and what is its purpose?

18.47 What is the principal advantage of a hammerhead tower crane over a conventional crawler crane?

18.48 Cargo hooks for helicopters used in construction have an additional hazard that is not present for cargo hooks for construction cranes. What is this additional hazard?

18.49 Is it okay to use a material hoist for personnel? What about vice versa? Explain.

18.50 Explain the terms *articulating* and *hydraulically extensible* with respect to vehicle-mounted boom platforms. Is it permissible for the boom to be both articulating and extensible?

18.51 Identify an example "engineering control" versus an example "administrative or work-practice control" for the hazard of personnel being run over by heavy construction equipment.

18.52 Explain the concept of "angle of repose" with respect to construction hazards.

18.53 Identify the two types of extraordinary stress on concrete forms that creates a need for overdesign to prevent forms kickout.

18.54 Although it is rare, an electrically fired explosive blasting cap can be set off by a stray electrical current. Name some possible sources of such stray currents that are mentioned in this chapter on construction hazards.

18.55 Which is more powerful, hydraulic tools or pneumatic tools? What additional advantage does the more powerful choice offer?

18.56 Extension cords lying on the floor or ground can be subjected to damage whether in a general industry setting or in construction. Why might damage be more likely in construction?

18.57 What alternative to GFCIs is permitted on construction sites? What are its advantages and disadvantages? Which has been found to be more costly, GFCIs or their alternative?

18.58 Is it okay to suspend incandescent electric lighting from flexible cords on construction sites? Explain any special conditions.

18.59 What two common methods are specified as alternative means of securing cleats on job-made ladders?

18.60 What design safety factor is specified for construction scaffolds? Is the safety factor the same for scaffold ropes supporting suspended scaffolds?

18.61 What alternative measure can be substituted for the careful and time-consuming task of monitoring of both minimums and maximums for scaffold plank overhang?

18.62 At what height do open-sided floors need guarding? Is the rule the same in the construction industry as for general industry? What differences exist? Offer a logical reason to explain any difference.

18.63 What factors make the back of a crane cab assembly especially dangerous?

18.64 Explain how a crane boom might come into contact with high-voltage utility transmission lines even when safe clearances are maintained according to standards.

18.65 What is a controlled decking zone (CDZ)? How is it different from a general walking and working surface?

18.66 Identify a tragedy in January, 2008, in which a worker fell 42 stories to his death.

RESEARCH EXERCISES

18.67 Construction and agriculture share many common hazards. Examine available data on agriculture hazards. Specifically, attempt to identify the single most common fatal farm accident. How many fatalities are estimated to occur each year due to this cause?

18.68 Less than 10 years after the Willow Island, West Virginia tragedy that took the lives of 51 construction workers, another accident of the same type occurred. Use the Internet or other sources to look up details of this second tragedy of the same type resulting in the highest number of construction fatalities since Willow Island.

18.69 **Research Case Study.** In an actual accident,[3] a construction worker was installing steel channel for a roof of a new building. He was using a fall protection system, by attaching his standard 6-foot lanyard to a line that ultimately connected to a rigid structure. However, the attachment line was an extra 10 feet of line looped between the lanyard and the rigid attachment. Since the 10-foot line was looped, its working length was half that: 5 feet. The worker was standing on a 10–inch beam, which was 20 feet off the concrete slab floor. This beam served as the rigid attachment for the worker's lifeline system. The worker lost his balance and accidentally fell. How far do you estimate that he fell? (*Hint: The answer is not 11 feet.*)

[3]The source of the information surrounding this accident has been withheld upon request.