

**CONSTRUCTION SAFETY AND HEALTH  
FOR CIVIL ENGINEERS**

**INSTRUCTIONAL MODULE**

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## ABSTRACT

The primary aim of this instructional module is to develop in the faculty and students an awareness of the many facets of safety and health, as applicable to civil engineering and construction work. Lack of a significant coverage of occupational and public safety and health topics in the related curricula has produced a gap of knowledge; this module attempts to fill this gap. Although a broad range of issues, concepts, principles and recommendations regarding construction safety and health are covered, this coverage is not intended to be comprehensive or exhaustive. Numerous references are provided in the module to lead the faculty and students into a vast wealth of knowledge in the fast changing field of safety and health engineering and management.

The module consists of seven units which can be utilized independently, or in desired combinations. It is envisioned that the information presented will be integrated in design and professional courses as a complement to the existing course materials, as deemed suitable. The loose-bound format in which the units are presented should allow future expansion and updates. Each unit starts with a set of goals and objectives, lists the key terms relevant to the covered topics, presents concise information on the subject matter, and contains a list of the cited references at the end. Review questions are also incorporated in each unit to guide the faculty and students to synthesizing the important parts of the contents, and developing detailed summaries of the material covered through the answers.

In the first unit of this module an introduction to the occupational safety and health problems in the construction industry is offered using statistical data, followed by a discussion of the needs for improving the industry's poor safety and health record, with special emphasis on the need for education and training. In the second unit, humanitarian, legal, institutional and economic concerns are described, stressing that accidents cost money and effective safety and health programs result in tangible savings. The third unit covers the salient points of safety and health legislation from a historical perspective, and presents information on the various federal and state agencies, and professional and trade organizations involved in safety and health.

The fourth unit of this module presents fundamental information on the causation of accidents, injuries and illnesses, and accident investigation, reporting, and prevention/control principles. The recognition and control of specific hazards associated with a variety of construction tasks and operations are covered in the fifth unit at some depth, with citations of the relevant OSHA standards. The sixth unit is devoted to the understanding of the causes of construction and structural failures through well-known case histories, along with the definition of the engineer's role (and liability) in the delivery of safe design and construction. Finally, in the seventh unit, the need for and the elements of effective company and project safety and health programs are discussed with emphasis on planning, organization, implementation and evaluation.

There may be several important topics related to construction safety and health not covered in this module, or covered in insufficient detail. The faculty and students are encouraged to identify and explore such topics through their own research. Also, some of the information presented, especially the information pertaining to regulations and standards, may become obsolete with time. It is the responsibility of the engineer to stay current in the field to effectively perform his/her professional duties.

## **UNIT I**

### **INTRODUCTION**

#### **PURPOSE**

To present an overview of the nature and magnitude of the safety and health problems in the construction industry, and emphasize the need for proper education and training on this topic, particularly for civil engineers.

#### **OBJECTIVES**

To familiarize the civil engineering faculty and students intending to utilize this unit with:

1. The entities involved in construction projects which may be concerned with jobsite safety and health
2. Unique aspects of the construction industry leading to its traditionally poor safety and health record
3. Statistical information on construction safety and health
4. The problems and needs in the construction industry concerning safety and health
5. The specific need for education and training on construction safety and health.

#### **KEY TERMS**

Construction industry; project team; owner; designer; A/E; CM; injury and illness statistics; incidence rates; occupational injury and illness; lost workdays; fatalities; accident surveillance; construction team interface; engineering needs; legal/legislative aspects; occupational health; primary safety exposures; education and training.

## UNIT I

### INTRODUCTION

#### CONSTRUCTION INDUSTRY

The construction industry in the United States is a \$500 billion/year industry (Construction Industry Institute estimate as annual output, 1987). About 90 percent (\$450 billion) of the total is new construction work, while 10 percent (\$50 billion) is maintenance and repairs (1). Over the years, construction has been a major contributor to the national economy. Presently, its share of the GNP is about 5 percent. In the 1970's this percentage was well above 10 percent. The construction industry employs over 5 million people annually availing 3 million full-time jobs. This number represents more than 5 percent of the national labor force. There are also about 1 million contractors and subcontractors engaged in construction work.

#### Project Team

Construction projects are conceived, planned, designed and built by a team usually consisting of the owner, designer-architect/engineer (A/E) and constructor (general contractor and subcontractors). A fourth entity, the construction manager (CM) may also be involved. In addition, support roles are played by material and equipment suppliers, financiers, insurers, regulators, and consultants. Workers carry out the construction tasks.

#### Unique Aspects

The construction industry is large but diffuse and fragmented, generally consisting of small units. A number of very large construction firms also exist, each doing more than \$1 billion business annually, often for very large corporate clients whose construction bills run to the billions of dollars. The industry undertakes diverse projects ranging in size from single family residential units to multibillion dollar power plants. The work may encompass general building construction (residential, non-residential, institutional, industrial), heavy construction (highways, public works infrastructure, utilities), and industrial construction (major industrial complexes such as refineries, power plants, steel mills, etc.). A significant part of construction work is done by special trade contractors, which perform plumbing; heating and air conditioning; painting and paper hanging; electrical work; masonry, stonework and plastering; carpentry and floor work; roofing, siding, and sheet metal work; concrete work; and other miscellaneous construction related work.

#### Differences with Other Industries

The construction industry is uniquely different from manufacturing and other industries, in that:

- . Its products are site produced and one-of-a-kind. With the exception of perhaps the housing sector, each project can be considered a "first, full-scale prototype."
- . The construction project is highly dependent on local conditions; i.e.

site, climate, local codes and regulations.

- . The work is very labor-intensive involving large forces and energies. The tasks are very variable; mass production and standardization are very difficult to achieve.
- . The industry brings together diverse entities such as designers, builders, planners, developers, skilled craftspeople, laborers, suppliers, distributors, managers, lawyers and regulators. These entities are joined together for a single project usually under complex arrangements, and are then dispersed upon completion of the work. The workforce is transient in most cases.

**Poor Safety  
Record**

Because of the inherent diversity and complexity of construction projects, the industry has traditionally suffered low productivity, a high degree of disputes, litigation and business failures, and a poor record of site safety.

**STATISTICAL  
DATA**

Several organizations collect, process, and publish information/statistics on occupational injuries and illnesses. The main ones are:

**Main Organizations  
Collecting Data**

- . The Occupational Safety and Health Administration (OSHA);
- . The Bureau of Labor Statistics (BLS);
- . The National Center for Health Statistics (NCHS);
- . The National Institute for Occupational Safety and Health (NIOSH);
- and
- . The National Safety Council (NSC).

OSHA and BLS are within the U.S. Department of Labor. NCHS and NIOSH are agencies housed in the U.S. Department of Health and Human Services. NSC is a voluntary association consisting of both individuals and organizations interested in promoting safety.

**Other Data  
Sources**

Injury and illness data are also compiled by the states (usually through their labor departments and workers compensation programs), and by insurance companies. While the states commonly publish these data, insurance companies in general do not.

**Discrepancies  
in Data**

In studying safety and health statistics, it is important to recognize that due to the different techniques and databases employed by different agencies in compiling their statistics, (e.g. sampling techniques, data analysis, using company reports, workers compensation data, death certificates, etc.), significant discrepancies may exist between their figures in reporting the same information.

**Incidence Rates**

Table I-1 summarizes the BLS estimates of the occupational injury and illness incidence rates per 100 full-time workers in different industries for 1990 and 1991. Table I-2 shows for 1991 the breakdown of the construction industry statistics into sectors represented by the various

**Table I-1**  
**BLS Estimates of Occupational Injury and Illness**  
**Incidence Rates by Industry Division, 1990-1991 (2)**  
Incidence Rates<sup>b</sup>

Industry Division	Total Cases <sup>c</sup>		Lost Workday Cases		Nonfatal Cases Without Lost Workdays		Lost Workdays	
	1991	1990	1991	1990	1991	1990	1991	1990
Private sector <sup>d</sup> .....	8.4	8.8	3.9	4.1	4.5	4.7	86.5	84.0
Agriculture, forestry, and fishing <sup>d</sup>	10.8	11.6	5.4	5.9	5.3	5.7	108.3	112.2
Mining.....	7.4	8.3	4.5	5.0	2.8	3.3	129.6	119.5
Construction.....	13.0	14.2	6.1	6.7	6.9	7.5	148.1	147.9
Manufacturing.....	12.7	13.2	5.6	5.8	7.1	7.3	121.5	120.7
Transportation and public utilities.	9.3	9.6	5.4	5.5	3.9	4.0	140.0	134.1
Wholesale and retail trade.....	7.6	7.9	3.4	3.5	4.1	4.4	72.0	65.6
Finance, insurance, and real estate	2.4	2.4	1.1	1.1	1.3	1.3	24.1	27.3
Services.....	6.2	6.0	2.8	2.8	3.3	3.2	60.0	56.4

<sup>a</sup> Standard Industrial Classification Manual, 1987 Edition (See Table I-2).

<sup>b</sup> Incidence Rate = (No. of injuries & illness x 200,000) OR (No. of lost workdays x 200,000)  
Total hours worked by all employees during period covered

where 200,000 is the base for 100 full-time equivalent workers (working 40 hours per week, 50 weeks per year).

<sup>c</sup> Includes fatalities. Because of rounding, the difference between the total and sum of the rates for lost workday cases and nonfatal cases without lost workdays may not reflect the fatality rate.

<sup>d</sup> Excludes farms with less than 11 employees.

**Table I-2**  
**BLS Estimates of Occupational Injury and Illness**  
**Incidence Rates for the Construction Industry, 1991 (2)**

Industry Sector	SIC Code <sup>a</sup>	Incidence Rates <sup>b</sup>			
		Total Cases <sup>c</sup>	Lost Workday Cases	Nonfatal Cases Without Lost Workdays	Lost Workdays
<b>Construction.....</b>		<b>13.0</b>	<b>6.1</b>	<b>6.9</b>	<b>148.1</b>
General building contractors.....	15	12.0	5.5	6.4	132.0
Residential building construction.....	152	9.7	4.9	4.9	122.5
Nonresidential building construction..	154	14.2	6.2	8.0	143.4
Heavy construction except building....	16	12.8	6.0	6.8	160.1
Highway and street construction.....	161	13.6	6.2	7.4	176.6
Heavy construction except highway..	162	12.4	5.9	6.5	153.2
Special trade contractors.....	17	13.5	6.3	7.1	151.3
Plumbing, heating, air-conditioning....	171	14.1	5.8	8.3	133.8
Painting and paper hanging.....	172	9.9	5.7	4.2	165.4
Electrical work.....	173	12.6	5.1	7.5	107.5
Masonry, stonework and plastering....	174	14.7	7.5	7.1	189.8
Carpentry and floor work.....	175	13.2	7.0	6.2	156.2
Roofing, siding, and sheet metal work	176	16.7	8.9	7.8	245.7

See footnotes on Table I-1 for a, b, and c.

Standard Industrial Classification (SIC) codes (2). The definitions of occupational injuries and illnesses and lost work days in these tables are as follows (3):

*Occupational Injury*

Occupational injury is any injury such as a cut, fracture, sprain, strain, amputation, etc., which results from a work event or from a single instantaneous exposure in the work environment.

*Occupational Illness*

Occupational illness is any abnormal condition or disorder, other than one resulting from an occupational injury, caused by exposure to factors associated with employment. It includes acute and chronic illnesses or diseases which may be caused by inhalation, absorption, ingestion, or direct contact of an agent.

*Total Cases*

Total cases include all work-related deaths and illnesses, and those work-related injuries that result in loss of consciousness, restriction of work or motion, transfer to another job, or require medical treatment other than first aid.

*Lost Workday Cases*

Lost workday cases are cases which involve days away from work, or or days of restricted work activity, or both.

*Nonfatal Cases*

Nonfatal cases without lost workdays are cases that do not involve fatalities or lost workdays but result in medical treatment other than first aid, restriction of work or motion, loss of consciousness, transfer to another job, or diagnosis of occupational illness.

*Lost Workdays*

Lost workdays are the number of workdays (consecutive or not) on which the employee would have worked but could not because of occupational injury or illness and/or the number of workdays (consecutive or not) on which, because for injury or illness, the employee was assigned to another job on a temporary basis; or worked at a permanent job less than full time; or worked at a permanently assigned job but could not perform all duties normally connected with it. The number of lost workdays does not include the day of injury or onset of illness or any days on which the employee would not have worked even though able to work.

**National Data on  
Incidence Rates**

A glance at Table I-1 reveals that construction is a leading industry in all categories of incidence rates. This situation has remained relatively unchanged over many years. Table I-2 shows that the problem is uniformly spread between all segments of the construction industry. The lost workday statistics suggest that certain specialty trade contractors, e.g. masonry, stonework and plastering workers, roofing, siding and sheet metal workers, and water well drillers have the highest incidence rates in the industry. One must recognize that a major part of the incidence rate statistics in construction relate to injuries rather than illnesses.

**Reliability  
of Data**

The reliability of the injury and illness data has been widely questioned (4). This is due to the belief that companies grossly underreport such information. BLS surveys exclude public sector employees, establishments with less than 11 employees, and the self-employed. Also, occupational illnesses, especially those which are chronic (as opposed to acute) with long latent periods, may be difficult to identify.

**NSC Data on  
Fatalities**

Fatalities and fatality rates (deaths per 100,000 workers) have been quite high in the construction industry compared to other industries. This is clearly displayed in Figures I-1 and I-2, which present data for the 1983-1992 period compiled by NSC (2). It is also observed from these figures that there has been a steady decrease in fatalities over this period, which is encouraging. However, the number and rate of fatalities in the construction industry are still very high, and are much above the average of all industries.

**NIOSH Data on  
Fatalities**

NIOSH also compiles and publishes fatality data. According to an earlier study (5), at least 6470 fatalities occurred in construction nationally between 1980 and 1985, which translates into 25.8 deaths per 100,000 workers per year. During the same period, the average fatality rate for all industries combined was 7.8 per 100,000 workers. Falls were the leading cause of death (26.0%), followed by electrocution (15.3%), machines (13.0%), motor vehicles (12.8%), and blunt force (10.4%). The remaining fatalities (22.5%) were due to miscellaneous causes which include drowning, explosions, homicide, suicide, and environmental factors.

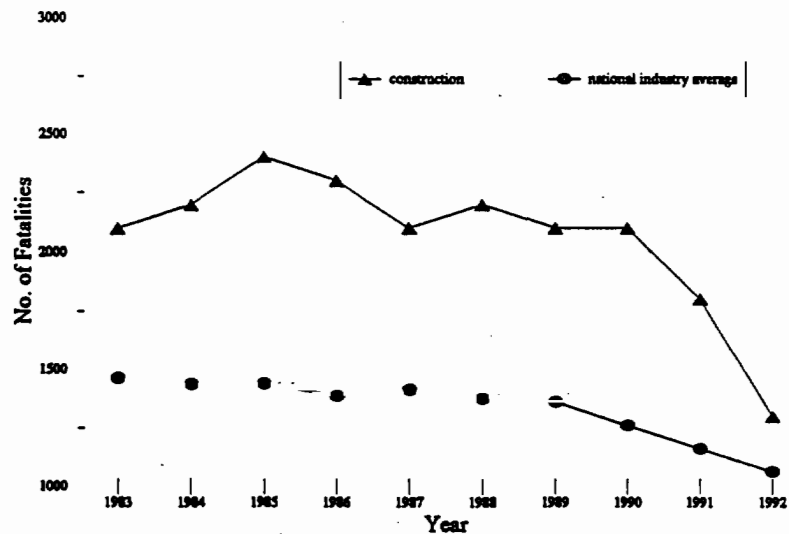
**State of  
Michigan Data**

*Injury Types*

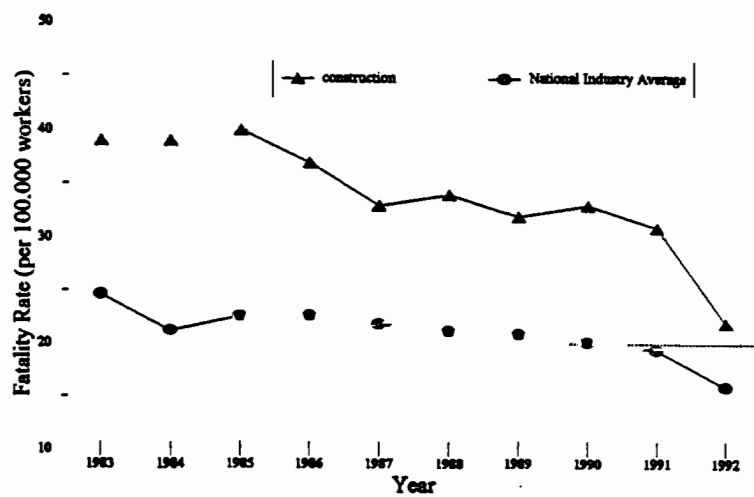
More detailed information on construction accidents, injuries and illnesses is usually available at the state level. For example, according to the statistics published by the Michigan Department of Labor (6), of the 6,853 construction industry cases reported in 1990, 65 (0.9%) were classified as amputation type of injury; 109 (1.6%) were burns due to heat; 31 (0.5%) were chemical burns; 440 (6.4%) were contusions and/or bruises; 843 (12.3%) involved cuts and lacerations; and 1,233 (18.0%) involved fractures. There were 126 (1.8%) scratches and abrasions, and 2,487 (36.3% - highest of all) sprains and strains. The occupational diseases totalled to 374 (5.5%), and the remaining 1,165 cases (17.0%) were classified as miscellaneous and non-classifiable.

*Part of Body  
Injured*

In reference to the same data, when considering the part of the body injured, 151 (2.2%) of the cases involved eye injuries, while 234 (3.4%) involved head and neck injuries. There were 647 (9.4%) finger injuries and 1,030 (15.0%) upper extremity injuries. Back, trunk and lower extremity injuries numbered 1,532 (22.4%), 909 (13.3%) and 1,649 (24.1%) respectively, comprising a significant part of the total. The remaining cases involved multiple body parts (515, or 7.5%), body system (145, or 2.1%), and non-classifiable body parts (41, or 0.6%).



**Figure I-1. Fatality Statistics for 1983-1992: Construction vs. National Industry Average**



**Figure I-2. Fatality Rate Statistics for 1983-1992: Construction vs. National Industry Average**

*Source of  
Injury or  
Illness*

In regard to the source of injury and illness, of the same 6,853 cases, 329 (4.8%) involved boxes, barrels and containers; 92 (1.3%) were caused by chemicals; and 673 (9.8%) were related to handtools. Machines, metal items and vehicles were respectively the source of injury and illness in 318 (4.6%), 854 (12.5%), and 301 (4.4%) of the cases. Wood items were involved in 331 (4.8%) cases, and working surfaces in 1,620 (23.6%). There were 2,335 (34.1%) cases attributed to other classifiable or non-classifiable sources.

*Type of  
Accident or  
Exposure*

The statistics regarding the type of accident or exposure revealed that 1,581 cases (23.1%) involved struck by or struck against type action; 1,771 (25.8%) were falls; 269 (3.9%) occurred as caught in or between objects; and 113 (1.6%) occurred as rubbed or abraded by objects. There were 530 (7.7%) cases involving bodily reaction and 1,917 (28.0%) overexertion. Contact with temperature extremes and radiation/caustic substances occurred in 109 (1.6%) and 116 (1.7%) cases, respectively. Motor vehicles were involved in 109 (1.6%) cases. The remaining 338 (4.9%) cases, again, were miscellaneous classifiable and non-classifiable accidents and exposures.

*Month, Day and  
Age Group*

Finally, the data showed that a larger number of cases occurred over the summer months as compared to other seasons, and Monday was the worst day of the week in terms of accident occurrence. The 25 to 34 year age group of the construction workers appeared to be most susceptible to accidents.

*Michigan Fatalities*

Michigan Department of Labor also provides statistics on construction-related fatalities (7). In 1988, construction led all other industries in the state in terms of fatality rate per 10,000 workers, except for the oil and gas extraction industry. The fatality rate for construction was 1.31 followed by agriculture, forestry and fishing (1.24), transportation and public utilities (0.47), manufacturing (0.18), wholesale trade (0.15), and services (0.08). Construction also led all the state industries in the number and percentage of fatalities. Of the total 61 fatalities, 17 (28%) occurred on construction job sites. A close second was manufacturing with 16 cases (26%). During the period from 1987 to 1992, construction fatalities were higher in number than manufacturing fatalities for four years out of seven despite a much larger workforce in the manufacturing industry. Construction led all industries in percentage of total fatalities during each year of the same period.

**Construction  
Work is Dangerous**

The national as well as Michigan statistics clearly point out that construction work is dangerous, and there exist significant problems concerning safety and health in the construction industry which need to be addressed. Although some improvement in certain indicators is apparent, the situation is nowhere it should be.

## **EXISTING PROBLEMS AND NEEDS**

In 1989, the Center for Excellence in Construction Safety conducted a National Forum on Construction Safety and Health Priorities (4). The event was sponsored by the National Institute for Occupational Safety and Health (NIOSH), along with several construction industry trade and professional organizations, bringing together over 150 representatives of the industry, labor and academia. The purposes of the forum were to define the prevailing critical issues, to prioritize them, and to generate strategies for potential solutions to the underlying problems.

### **Critical Issues**

The forum identified seven critical issues needing attention by the industry. These were:

- . Accident surveillance;
- . Construction team interface;
- . Engineering needs;
- . Legal / legislative aspects;
- . Occupational health;
- . Primary safety exposures; and
- . Education and training.

### **Accident Surveillance**

Concerns about accident surveillance covered proper and meaningful data collection, accident reporting requirements and procedures, data analysis and contractual aspects, including liability issues. It was suggested that a vastly improved system of accident surveillance is needed to help contractors and regulatory agencies acquire the data significant to the understanding and solution of the problems. Training of the pertinent personnel on the effective implementation of all of the surveillance related tasks was also recommended.

### **Construction Team Interface**

With respect to construction team interface, it was very clear that the overriding problem revolves around the lack of a real understanding of the roles and responsibilities for safety and health by the project participants, i.e. the owner, A/E, contractor, CM, and workers. It was recognized that safety and health in the construction industry was not managed in the same manner as cost, quality, schedule and productivity, mainly due to the lack of appropriate education and training in this area. The recommendation was to make the industry fully understand the economic benefits of effective safety and health programs, and that owners should screen contractors based on their safety and health records.

### **Engineering Needs**

Engineering needs dealt with the application of engineering principles and skills to accident prevention, particularly with respect to construction erection systems, the construction process, equipment design and accident data. It was contended that many construction accidents and failures can be prevented by proper engineering. There is a need for sound structural design rationale for temporary erection systems and criteria for acceptable risk in various situations and environments. The need for standardization of the layout controls and

operating procedures for construction equipment based on ergonomics principles, and an effective accident data collection and analysis system were also stressed.

**Legal/  
Legislative  
Aspects**

The role and effectiveness of the Occupational Safety and Health Administration (OSHA) was recognized as the single most important area of concern in regard to legal and legislative aspects. It was suggested that OSHA was not particularly effective in accident prevention due to its focus on regulatory compliance and penalties, and not on providing the appropriate education, training and incentives for the contractor to work safely. The problem of inconsistency in the interpretation of standards by OSHA personnel was emphasized. Performance based safety and health standards for contractors were advocated.

**Occupational  
Health**

On occupational health, the primary concern was over the applicability of the OSHA Hazard Communication Standard to the construction industry, although its benefits were readily acknowledged. The need was expressed for a medical screening and monitoring system tailored to the requirements and potential exposures of the job. The need for effective safety and health programs with clearly assigned responsibilities emphasizing the health aspects and hazard control was also pointed out, with the suggestion that a model Safety and Health program be developed at the project level.

**Primary Safety  
Exposures**

The root causes of accidents were explored with respect to the primary safety exposures. Six problem areas were identified: 1) lack of company programs and written rules; 2) lack of basic, specific and continuing training; 3) lack of planning, organization, motivation, communication and control; 4) lack of a sound value system, i.e. attitude, loyalty, sensitivity, etc.; 5) poor work practices and improper procedures; and 6) lack of accountability and responsibility. The key factors for solutions to these problems were identified as effective education and training, and the implementation and enforcement of well-designed safety and health programs.

**Education and  
Training**

Education and training was recognized, by far, as the most important issue and need in the construction industry at all levels, from owners, architects, design engineers, and construction management personnel, all the way through the site supervisors and foremen to the workers. Lack of adequate education and training was cited as part of many problems relating to construction safety and health, and the need for it was frequently and strongly emphasized for devising effective solutions to the problems. It was suggested that an awareness of safety and health needs to be fostered by training in this area, and must be phased into the educational system very early, such as in grade schools and vocational training centers. It was particularly recommended that safety and health education become a required part of the engineering curriculum in the United States.

## **CONTENTS OF THE MODULE**

This instructional module responds to the critical need for the development of a resource document for use by civil engineering faculty and students in the area of construction safety and health. Many graduates of Civil Engineering programs frequently find themselves in responsible positions as employees of or consultants to construction project participants, having little or no background or training in safety and health. Their knowledge on this important topic may be less than adequate for providing the optimal professional service in design, management, or supervision. Traditionally, the emphasis in civil engineering curricula has been on the safety of a facility as designed or constructed, and little attention has been given to public safety and health, and occupational safety and health during the construction process. Most of the knowledge on work site safety and health has been gained, and to a large extent continues to be acquired, through experience on the job. It is hoped that this module will fill an important gap which exists in the civil engineering curriculum, affording opportunities for teaching and learning the significance, principles and practice of construction safety and health.

### **Following Units**

In the following units of this instructional module we will present state-of-the-art information on the rationale for safety and health, legislative aspects and related organizations, principles of accident analysis and injury control, construction industry safety and health practices and standards, engineering, design and contract administration for safe construction, and management of safety and health in construction projects.

### **REVIEW QUESTIONS**

1. What are these unique aspects of the construction industry leading to the poor safety and health record of the industry?
2. Name and discuss the organizations which collect, process and publish statistical information on occupational safety and health.
3. What is meant by the term incidence rate? What types of incidence rates are compiled by the Bureau of Labor Statistics?
4. What types of statistical information on occupational safety and health are available from the Michigan Department of Labor? What is the significance of this information?
5. List and discuss the seven critical issues (needing attention) that were established at the National Forum on Construction Safety and Health Priorities organized in 1989 by CECS. Which one of these issues do you think is the most important? Why?

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## **UNIT II**

### **WHY SAFETY AND HEALTH**

#### **PURPOSE**

To introduce civil engineering students to the need and significance of addressing the safety and health issues presented by a construction project.

#### **OBJECTIVES**

In regards to safety and health, to acquaint the student with:

1. Humanitarian concerns
2. Legal/regulatory concerns
3. Institutional concerns
4. Economic concerns
5. Direct and indirect costs of accidents
6. Insurance considerations and experience modification rating (EMR)
7. Savings realized through safety and health programs
8. Accident cost accounting systems.

#### **KEY TERMS**

Concerns for safety and health; humanitarian; legal and regulatory; institutional; economic impact; accident direct costs; indirect costs; workers compensation insurance; liability insurance; property insurance; manual rate; experience modification rating (EMR); multiplier; accident cost accounting; safety program costs; safety program savings.

Insurance costs = 1% + 7% = 8% of direct labor costs;  
 Accident claims costs = 65% x 8% = 5.2% of direct labor costs;  
 Indirect costs = 1 + 5.2% = 5.7% of direct labor costs

**Table II-4**  
**Accident Cost Schedule in 1979 Dollars (7)**

Body part	Amputation	Injury type											
		Strain sprain crush, mash smash		Fracture		Cut puncture laceration		Burn		Bruise abrasion		Other	
		Non- Lost time	Lost time	Non- Lost time	Lost time	Non- Lost time	Lost time	Non- Lost time	Lost time	Non- Lost time	Lost time	Non- Lost time	Lost time
Head, face	NA	NA		700	8,000	250	3,000	325	7,500	250	1,000	350	6,000
Eye(s)	(1) 45,000 (2) 245,000	NA		NA		250	3,000	200	5,000	300	1,000	300	5,000
Neck and shoulder	NA	350	7,000	1,500	8,000	250	3,000	325	5,000	250	2,000	300	7,000
Arm(s) and elbow(s)	(1) 190,000 (2) 250,000	350	4,000	1,000	6,000	250	3,000	250	5,000	300	3,000	250	6,000
Wrist(s) and hand	(1) 52,000 (2) 250,000	275	2,500	700	9,000	250	3,000	325	5,000	250	4,000	350	8,000
Thumb(s) and fingers	8,000 ea. up to 37,000	275	2,500	350	5,000	250	3,000	200	5,000	200	3,000	200	5,000
Back	NA	2,000	10,000	NA	100,000	250	3,000	325	7,500	320	5,000	350	10,000
Chest and lower trunk	NA	450	4,000	NA		250	8,000	325	5,000	250	3,000	250	9,000
Ribs	NA	350	1,000	450	4,000	NA		325	5,000	350	3,000	300	9,000
Hip	NA	NA	3,500	450	12,000	200	3,000	325	5,000	350	5,000	450	4,000
Leg(s) and knees	(1) 89,000 (2) 280,000	375	4,000	500	15,000	250	3,000	325	5,000	250	3,000	300	8,000
Foot (feet) and ankle(s)	(1) 44,000 (2) 90,000	300	2,500	450	9,000	200	2,500	300	3,000	280	1,000	350	2,000
Toe(s)	7,000 ea. up to 40,000	300	1,500	200	2,500	250	3,000	325	2,000	200	1,000	220	2,000
Hernia rupture												200	8,000
Heart attack													30,000
Hearing loss													10,000
Death													90,000

**Table II-5**  
**Accident Cost Estimating System (ACES) Multiplier Sheet (8)**

Injury Type or Body Part	Amputation	Strain, Sprain, Crush, Smash, Mash	Fracture	Cut, Puncture Laceration	Burn	Bruise Abrasion	Other
Eyes(s)	5.3K-28.8K	NA	NA	35 - 350	25 - 610	35 - 120	35 - 610
Head/Face	NA	NA	80 - 960	35 - 350	40 - 880	35 - 120	40 - 720
Neck and Shoulder	NA	40 - 830	175 - 960	35 - 350	40 - 610	35 - 240	35 - 830
Arm(s) and Elbow(s)	24.4K-28.8K	40 - 480	120 - 720	35 - 350	35 - 610	35 - 610	35 - 720
Wrist(s) & Hands	6.1K-28.8K	35 - 305	80 - 1.4K	35 - 350	40 - 610	35 - 380	40 - 720
Thumb(s) & Finger(s)	960@	35 - 305	40 - 610	35 - 350	25 - 610	25 - 610	25 - 610
Chest & Trunk	NA	55 - 480	NA	35 - 960	40 - 610	35 - 350	35 - 1.1K
Rib(s)	NA	40 - 120	55 - 480	NA	40 - 610	40 - 350	35 - 1.1K
Back	NA	249 - 1.2K	NA - 11.8K	35 - 350	40 - 880	40 - 610	40 - 1.2K
Hip(s)	NA	NA - 415	55 - 1.4K	25 - 350	40 - 610	40 - 610	55 - 480
Leg(s) & Knee(s)	10.6K-33.6K	50 - 480	55 - 1.8K	35 - 350	40 - 610	35 - 350	35 - 960
Foot/Feet & Ankle(s)	6.1K-10.6K	35 - 305	55 - 1.0K	25 - 350	35 - 350	35 - 120	40 - 240
Toe(s)	830@	35 - 175	25 - 305	35 - 350	40 - 240	25 - 120	35 - 240
Hernia Rupture	NA	NA	NA	NA	NA	NA	35 - 960
Special Consideration:	Heart Attack =	1.5K - Hearing	Loss = 1.2K	Death = 10.6K			

### Revised Example

Referring to the accident cost example described above involving the lost workday hand injury (fracture), the multiplier is found from Table II-5 as 1,400. If the wage rate (including fringe benefits) for the worker is \$20 per hour, the cost of this accident will amount to  $\$20 \times 1,400 = \$28,000$ .

Note that this figure is based on rate adjustments for the period from 1979 to 1988 and does not account for the inflation rate beyond. Please also note again, the multipliers on this table are simply representative values, and they can be adjusted based on company specific data.

### REVIEW QUESTIONS

1. What are the principal concerns in the construction industry regarding safety and health?
2. How does the workers compensation insurance work for contractors? How does EMR affect their competitiveness?
3. List and discuss the possible direct and indirect costs associated with the following accident. State all your assumptions, and provide a total cost estimate for this accident.

### CASE STUDY

The deceased was on top of a mobile scaffold 15 feet above the level of the third floor. Another employee was cutting wooden braces and handing them up to him. The day was windy and the canvas sheets 15'x 20' and 20'x 20' were in use, hanging from the roof level to the third floor level on the outside of the building, to protect the freshly poured concrete from freezing. The scaffold was positioned near the end of the building. The wind blew the canvas sheet into the scaffold and knocked it over. The deceased fell to the concrete surface of the third floor. He died the next day in the hospital from injuries received. The second employee was able to jump out of the way of the falling scaffold.

4. Summarize by sample calculations how money invested in company safety and health programs provides savings. Will the savings increase or decrease if the indirect to direct cost ratio (multiplier) increases?
5. What are the advantages of instituting an accident cost accounting system in the course of performing construction work?
6. Describe the main features of the Stanford Accident Cost Accounting System.

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### **UNIT III**

## **CONSTRUCTION SAFETY AND HEALTH LEGISLATION AND ORGANIZATIONS**

### **PURPOSE**

To familiarize the students with the historical background of legislative developments in the area of safety and health (with special focus on construction), and to list and summarize the roles and responsibilities of the main public, private and professional organizations involved in construction safety and health.

### **OBJECTIVES**

To present information on:

1. The historical perspective on the legislative developments at the federal and state levels concerning safety and health
2. The Occupational Safety and Health Act of 1970; its significance and impact
3. OSHA, OSHRC and NIOSH and other organizations dealing with safety and health
4. Present state of construction safety and health related legislation.

### **KEY TERMS**

Labor legislation; federal acts; state workers compensation laws; OSH Act; OSHA; OSHRC; NIOSH; safety and health standards; employers; employees; workplace inspections; imminent danger inspection; catastrophies and fatalities; employee complaints; special inspections; programmed inspections; violations; de minimis; other than serious; serious; willful; repeated; imminent danger violation; citations; compliance officer; education and training; consultation; federally approved state plans; safety and health organizations; civil penalties; criminal sanctions; Comprehensive OSHA Reform Bill.

### UNIT III

## CONSTRUCTION SAFETY AND HEALTH LEGISLATION AND ORGANIZATIONS

#### **HISTORICAL BACKGROUND ON SAFETY AND HEALTH LEGISLATION**

Before the nineteenth century, America was mainly an agrarian society. With the industrial revolution occurring in the second half of the nineteenth century, the way of life started to change quickly with people moving from the countryside to urban areas looking for work. The working conditions in many factories and other establishments were very unsatisfactory: work areas were overcrowded; ventilation, lighting and sanitary conditions were very poor; and workers (many of whom were women and children) usually worked 14 to 16 hours a day. In general, illnesses, accidents, and even deaths caused by poor working conditions in these work places were accepted as inevitable.

#### **Anglo-American Common Law**

Under Anglo - American common law, workers could sue their employers for damages or injuries incurred in employment, but the same law provided strong defenses for the employers through considerations of contributory negligence by the injured employee; negligence by others; and knowledgeable assumption of risk by the employee (1).

#### **Necessity for Compensation**

Although labor legislation protecting workers and compensation laws were present in Europe in the nineteenth century (Germany, England, France), little was done on safety legislation in the U.S. Nevertheless, in 1867, Massachusetts initiated labor/safety related laws involving factory inspections, labor statistics, and limitation of daily working hours to 10. Other states joined with their own legislation later in the century. Not until the early 1900's had sentiment begun focusing on worker protection and compensation. The famous "Pittsburgh study" undertaken in 1907-1908 documented, for the first time, the number of industrial fatalities in Allegheny county (526) in one year, and concluded that the cost of work accidents almost exclusively fell on the workers and their families. This finding underscored the necessity for a system of compensation to achieve justice, social expediency and prevention (2).

#### **Early Federal Legislation**

The first federal legislation on workers compensation was enacted by Congress in 1908 - for federal employees only, with a limited scope. In 1910, the U.S. Bureau of Mines was established in the Department of the Interior to reduce mine accidents (after the 1907 Monongah, West Virginia mine disaster killing 362 miners). In 1913, the Bureau of Labor Statistics was organized to collect, tabulate and disseminate facts about industrial accidents and health problems. The National Bureau of Standards began issuing safety standards for industrial materials and equipment the same year.

## **State WC Laws**

At the state level, Maryland (1902) and New York (1910) passed the first workers compensation laws but these were declared unconstitutional based on the 14th amendment. In 1911, Wisconsin and Washington passed the first "constitutional" workers compensation laws. By 1928, 43 states had them; by 1948 all 48 states had workers compensation laws. Also, Departments of Industrial Hygiene and Safety were formed to provide education and conduct safety inspections in many states.

## **More Recent Federal Legislation**

More recent federal legislation dealing with safety and health includes:

- . Establishment of Bureau of Labor Standards in the Department of Labor (1934), which was the first permanent federal agency with a mandate to promote safety and health for the entire workforce.
- . Social Security Act (1935), which provided Public Health Service (PHS) funding for the states, and barred persons under 18 from working in "dangerous" jobs.
- . Walsh - Healy Act (1936), which confirmed the federal regulatory role of the Department of Labor concerning job safety and health.
- . McNamara - O'Hara Act (1966) and Construction Safety Act (1969), which extended federal regulations to service contract employers, and federally funded construction employers, respectively.
- . Coal Mine Health and Safety Act (1969), following a mine explosion in Farmingdale, West Virginia killing 78. This Act was amended in 1977 to include Department of Labor enforcement.

## **OSH ACT OF 1970**

Without question, the most significant, comprehensive and far reaching legislation relative to occupational safety and health in the United States has been the Occupational Safety and Health (OSH) Act of 1970. There had been strong sentiment among industry representatives, labor groups and safety organizations that a federal agency was needed to set safety standards and enforce them, if significant improvements were to be expected in safety and health conditions in the U.S. work places. Based on this demand, in 1970, it was found by the U.S. Congress that occupational injuries and illnesses imposed a substantial burden upon, and were a hindrance to, interstate commerce in terms of lost production, and wages, medical expenses, and disability compensation payments. In response to this situation, the OSH Act was passed on December 28, 1970. Co-authored by Senator Williams (Dem. - N.J.) and Congressman Steiger (Rep. - Wis.), the Act became effective on April 28, 1971. The provisions of the Construction Safety Act of 1969 were included in this act by reference.

## **Aim and Coverage**

The basic aim of the OSH Act is to ensure, "so far as possible, every working man and woman in the nation safe and healthful working conditions and to preserve our human resources," through reduction of work place hazards. The OSH Act requires that each employer furnish his employees a work place free from recognized hazards that are causing or likely to cause death or serious physical harm. Under the

Act, both the employers and the employees are required to comply with the promulgated safety and health standards. With only a few exceptions, the Act applies to every employer who has one or more employees. Employers with 11 or more must keep records of all work-related injuries and illnesses. The Act is not applicable to farm employees who are family of the employer, to the self-employed, and to employees at work places that are covered by other federal agencies.

### **Agencies**

The OSH Act created three agencies:

- 1) **The Occupational Safety and Health Administration (OSHA)** - within the Department of Labor - to administer the Act, headed by an Assistant Secretary of Labor. OSHA is responsible for the establishment of safety and health standards and the rules and regulations to implement them.
- 2) **The Occupational Safety and Health Review Commission (OSHRC)** - an independent body to hear and settle cases in which employers contest actions started by OSHA.
- 3) **The National Institute for Occupational Safety and Health (NIOSH)** - within the Department of Health and Human Services - to conduct research and education, and develop data, criteria and recommended standards for OSHA.

### **The Roles of States**

Under the OSH Act, each state was allowed to promulgate its own version of the OSHA act, as long as the state's plan was at least as strict as the federal standards. If a state exercises its right under the Act to enact a safety and health plan meeting this criteria, then it becomes the sole safety and health agency within that jurisdiction. Otherwise, federal jurisdiction prevails over the state's employers. Construction in that state is then subject to inspection by both Federal and State safety inspection agencies.

### **OSHA'S ROLE IN SAFETY AND HEALTH**

In administering the OSH Act, OSHA performs four main functions; these are:

- 1) To set standards;
- 2) To conduct work place inspections;
- 3) To issue citations to employers, who violate the standards, sometimes assessing fines; and
- 4) To offer employers assistance in reducing the work place hazards.

### **OSHA Inspections**

OSHA conducts numerous inspections each year, while the states and territories operating their own job safety and health programs conduct many additional visits. However, there are more than five million work places covered by the OSH Act. Recognizing that OSHA can not possibly reach all these work places, a system of inspection priorities has been established. The idea behind this system is to focus the agency's limited resources on work places that present the greatest hazards to employee health and safety.

## **Inspection Priorities**

### *Imminent Danger*

OSHA's order of inspection priorities are as follows (3):

1) Imminent danger is top priority, and represents a condition where there is reasonable certainty that a danger exists and can be expected to cause death or serious physical harm immediately. If not corrected, the situation would most likely result in an accident causing severe or permanently disabling injury.

### *Catastrophies and Fatalities*

2) Catastrophes and fatalities is represented by accidents and fatalities resulting in the hospitalization of five or more employees. Such occurrences must be reported to OSHA within 8 hours. Investigations are made to determine if OSHA standards were violated and to avoid recurrence of similar accidents.

### *Employee Complaints*

3) Employee complaints are based on alleged violations of standards. The Act gives each employee the right to request an OSHA inspection if he or she feels there is an imminent danger from a hazard, or there is a violation of an OSHA standard. The identity of the complainant can be kept confidential, if requested.

### *Special Inspection Programs*

4) Special inspection programs target specific hazards and specific industries for which problems are perceived. Recent examples have included trenching operations, and chemical plants producing hazardous chemicals.

### *Programmed Inspections*

5) Programmed inspections involve random visits targeted at high-hazard industries, occupations, or substances. Targeting is based on high illness or injury incidence rates. Special emphasis may be regional or national in scope, depending on the distribution of the workplaces involved.

## **Compliance Officer's Role**

OSHA inspections are performed by compliance officers. Originally, it was the intent that all inspections would be conducted without advance notice to the employer, so the potential for surprise inspection provided an incentive for all employers to eliminate or reduce hazards. However, it has turned out that according to the Fourth Amendment, the employer may request a warrant before the start of the inspection (4). Once on site, the function of the compliance officer is to identify and measure conditions and/or acts which are considered unsafe and in violation of OSHA safety and health regulations. In the pursuit of his duties, he may go wherever he wishes on the project. He may take samples or measurements. He can request copies of literature, documents or contracts which relate to safety or industrial hygiene. The compliance officer may consult with employees regarding matters of safety and health to the extent necessary for the conduct of an effective and thorough inspection.

## **Violations**

A citation is issued by the compliance officer when violations of OSHA standards are observed. The OSH Act provides the basis for determining six classifications of violations:

### *De Minimis*

1) De Minimis violations are those that have no direct or immediate relationship to job safety and health (e.g. not posting the phone number of the "nearest medical facility").

*Other than  
Serious*

2) Other than serious violations may have a direct relationship to job safety and health but probably would not cause death or serious physical harm (e.g. a tripping hazard not leading to a serious fall).

*Serious*

3) Serious violations would be related to situations where death or serious physical harm could result, and the employer knew, or should have known, of the existence of the hazard (e.g. missing guard rails on elevated platforms).

*Willful*

4) Willful violations involve cases where there is evidence that the employer was aware that a hazardous condition existed, yet made no reasonable effort to eliminate it (e.g. ignoring warnings of employees, safety inspectors, etc. regarding an existing hazard).

*Repeated*

5) Repeated violations occur when a previously cited violation is found to have not been corrected upon reinspection.

*Imminent  
Danger*

6) Imminent danger is a violation where a hazard exists which could cause death or serious physical harm immediately, or before it can be eliminated through regular enforcement procedures. This may necessitate legal action through federal district court if the employer fails to correct it without delay.

**Criminal  
Prosecution**

OSHA is structured to essentially regulate the industry through the threat of civil penalties. Only when a violation of an OSHA standard causes an employee's death is a criminal sanction possible. Since OSHA has been generally reluctant to bring criminal cases to the courts, individual state and local prosecutors have become increasingly aggressive in using general criminal laws (e.g. man slaughter, assault, etc.) to indict employers for creating unsafe workplace conditions (5).

**OSHA's Training  
and Education  
Programs**

OSHA indicates that voluntary compliance is preferable to compliance that has to be forced through citations and penalties. In 1989, 14% of OSHA's \$248 million budget was devoted to educating the work force (3). OSHA's Office of Training and Education conducts programs in the recognition, avoidance, and prevention of unsafe and unhealthful working conditions (6). Employers and employees can receive training at the state and local level. The OSHA Training Institute trains personnel from OSHA, other federal agencies, and employers and employees. For further information, contact:

**OSHA Training Institute  
155 Times Drive  
Des Plaines, IL. 60018  
(312) 297-4810.**

## **Consultation Assistance**

Employers may obtain free consultation assistance under the consultation program, which is funded by OSHA and conducted by the states. While the short-term goal is to identify hazards facing employees, the long-term goal is to provide guidance in establishing, or improving the company's safety program. OSHA's consultation program is completely separate from its inspection program. No citations or penalties are issued; however, the participants are obligated to correct serious job safety and health hazards promptly. The thrust of the program is to create a work environment which promotes health and safety, rather than one which must react to crisis situations. For additional information concerning consultation assistance, including a directory of OSHA-funded consultation projects, refer to OSHA publication No. 3047 (7).

## **Regional and Area Offices**

Federal (national) OSHA offices are located in the Department of Labor building in Washington, D.C. However, OSHA performs its enforcement activities from regional and area offices throughout the United States. A list of the 10 Department of Labor Regional Offices is provided in Table III-1. Note that each region also has a number of area offices serving as resource centers, as well as administering the enforcement activities. These are listed in the same table. The status of the states (and territories) in these regions are also indicated in Table III-1. Approved Plan States are those which have their own plans and jurisdictions. The Federal Plan States are those which do not have approved plans and are directly under OSHA's jurisdiction. Note that the information provided in Table III-1 on the status of the state (and territory) plans pertain to 1994. The situation may change in the future.

## **Office of Construction and Engineering**

In recognition of the existence of critical safety and health problems in the construction industry, OSHA in 1990 established the Office of Construction and Engineering within the National Office in Washington, D.C. The mission of this office is "to serve as OSHA's principal source on advising Agency components with respect to construction and engineering activities and issues involved in the overall occupational safety and health field, and to provide technical assistance and support to all other National Office and regional organizations of the Agency with regard to construction activities" (8). Composed of Engineering and Construction branches, the Office serves the following functions:

### ***Functions***

- 1) Acting as technical construction advisor to the Assistant Secretary on the impact of policy, technical, and field questions with regard to the construction industry;
- 2) Providing construction safety responses to evaluate serious and/or unusual problems and provides technical assistance to the Agency in emergency situations;
- 3) Coordinating the activities of the Office with other National Office Directories and Offices;
- 4) At the request of a region, participating in providing technical

**Table III-I**  
**OSHA Federal, Regional and Area Offices & Status of State Plans (1994)**

OSHA (National Office)  
U.S. Dept. of Labor  
Occupational Safety & Health Administration  
200 Constitutional Avenue - Washington, D.C. 20210  
(202) 523-8271 or (202) 523-8151

**State Plan      Federal Plan**

OSHA Region I  
1 Dock Square Bldg. 4th flr.  
16-18 North St.  
Boston, MA 02109  
(617) 565-7164

CT	MA
VT	ME
NH	
RI	

**Area Offices:** Boston, MA; Concord, NH; Providence, RI; Springfield, MA; Augusta, ME; Hartford, CT.

OSHA Region II  
1515 Broadway, Rm 3445  
New York, NY 10036  
(212) 337-2378

NY	NJ
PR	
VI	

**Area Offices:** Manhattan, NY; Long Island, NY; Queens, NY; Albany, NY; Syracuse, NY; Buffalo, NY; Puerto Rico, PR; Hasbrouck Heights, NJ; Avenel, NJ; Dover, NJ; Camden, NJ.

OSHA Region III  
Gateway Building, Suite 2100  
3535 Market St.,  
Philadelphia, PA 19104  
(215) 596-1201

MD	DC
VA	DE
PA	
WV	

**Area Offices:** Philadelphia, PA; Wilmington, DE; Wilkes-Barre, PA; Allentown, PA; Pittsburgh, PA; Erie, PA; Baltimore, MD; Charleston, WV; Harrisburg, PA; Richmond, VA.

OSHA Region IV  
1374 Peachtree St., N.E. Suite 587  
Atlanta, GA 30367  
(404) 347-3573

KY	AL
SC	FL
TN	GA
	MS
	NC

**Area Offices:** Atlanta, GA; Columbia, SC; Savannah, GA; Birmingham, AL; Fort Lauderdale, FL; Jacksonville, FL; Tampa, FL; Jackson, MS; Mobile, AL; Nashville, TN; Frankfort, KY; Raleigh, NC.

**Table III-1. (Continued)**

	<b>State Plan</b>	<b>Federal Plan</b>
<b>OSHA Region V</b> 32nd Floor, Rm. 3244 230 South Dearborn St. Chicago, IL 60604 (312) 353-2220	IN MI MN	IL OH WI
<b>Area Offices:</b> Calumet, IL; Niles, IL; Aurora, IL; Cincinnati, OH; Cleveland, OH; Columbus, OH; Indianapolis, IN; Toledo, OH; Appleton, WI; Eau Claire, WI; Milwaukee, WI; Madison, WI; Minneapolis, MN; Peoria, IL; Belleville, IL; Detroit, MI.		
<b>OSHA Region VI</b> 525 Griffin Sq. Bldg., Rm. 602 Dallas, Tx 75202 (214) 767-4731	NM LA OK TX	AR
<b>Area Offices:</b> Dallas, TX; Albuquerque, NM; Corpus Christi, TX; Houston, TX; Little Rock, AR; Austin, TX; Baton Rouge, LA; Lubbock, TX; Oklahoma City, OK.		
<b>OSHA Region VII</b> 911 Walnut St., Rm 406 Kansas City, MO 64106 (816) 426-5861	IA MO NE	KS
<b>Area Offices:</b> Kansas City, MO; Des Moines, IA; Omaha, NE; St. Louis, MO; Wichita, KS.		
<b>OSHA Region VIII</b> Federal Building, Rm 1576 1961 Stout St., Denver, CO 80204 (303) 844-3061	UT WY ND SD	CO MT
<b>Area Offices:</b> Billings, MT; Bismarck, ND; Denver, CO; Salt Lake City, UT.		
<b>OSHA Region IX</b> 450 Golden Gate Ave., Box 36017 San Francisco, Ca 94102 (415) 744-6670	AZ CA HI NV	American-Samoa Guam Trust Territories of the Pacific
<b>Area Offices:</b> Berkeley, CA; Long Beach, CA; Phoenix, AZ; Honolulu, HI; Las Vegas, NV.		
<b>OSHA Region X</b> Federal Office Bldg., Rm 6003 909 First Ave. Seattle, WA 98101-3212 (206) 553-5930	AK OR WA	ID
<b>Area Offices:</b> Anchorage, AK; Bellevue, WA; Boise, ID; Portland, OR.		

assistance to State government agencies;

5) Keeping abreast of changes in developments in the construction industry to execute construction and overall occupational safety and health engineering feasibility programs;

6) Coordinating Agency interaction with the Advisory Committee on construction safety and health and its working groups; and

7) Providing a variety of technical information to the OSHA Training Institute regarding training activities and courses in the construction field.

### *Staff*

The Office of Construction and Engineering is staffed with civil, structural and geotechnical engineers, and construction safety specialists who perform accident and construction failure investigations, provide technical support to regional offices, offer technical expertise in the development of safety standards, and participate in the development and delivery of OSHA training programs.

### **OSHRC**

The Occupational Safety and Health Review Commission (OSHRC) is a quasi judicial board of 3 members appointed by the President and confirmed by the U.S. Senate. It has a corps of administrative law judges based in field offices located in regional offices in Atlanta, Boston, Dallas, Denver, and Washington D.C. If an employer inspected by OSHA receives a citation or a penalty with which he does not agree, he has 15 working days to inform OSHA in writing that he is contesting the citation or penalty. The case then is handled by OSHRC, through an administrative law judge. Based on its findings, the Commission may agree with, modify, or overrule OSHA's findings. A publication titled Occupational Safety and Health Reporter published by Bureau of National Affairs provides the full text of court decisions on occupational safety and health and of decisions of the OSHRC, and digests of Review Commission judges' reports that become the final orders of the Commission. The address and telephone number for this body is:

**Occupational Safety and Health Review Commission**  
1625 K Street  
Washington, D.C. 20006  
(202) 634-7960.

### **NIOSH**

The OSH Act established the National Institute for Occupational Safety and Health (NIOSH) to provide services in research, training, and technical assistance for occupational safety and health. The four main functions of NIOSH are:

#### **Main Functions**

- 1) To develop criteria for recommended standards for job safety and health;
- 2) To conduct research experiments and surveys on various issues related to job safety and health, including psychological factors;
- 3) To provide technical assistance; and

- 4) To conduct education and training programs for professional personnel who carry out OSH Act functions.

**Additional  
Functions**

NIOSH also recommends limits for exposure to known dangerous substances. Employers and employees can obtain technical assistance from NIOSH on services such as evaluation of hazards determined from on-site tests; work place health and safety conditions and preventive measure information; accident prevention; industrial hygiene (health); and medical services.

**Personnel**

To address health and safety problems of American workers, NIOSH employs scientists, physicians, nurses, engineers with various specialities, chemists, physicists, industrial hygienists, epidemiologists, toxicologists, behavioral scientists, ergonomists, physiologists, psychologists, and sociologists, as well as statisticians, educational specialists, and writers.

**Organization**

Since 1973, NIOSH is a part of the Centers for Disease Control and Prevention (CDC) which is the U.S. Public Health Service (PHS) agency for promoting health and preventing disease. NIOSH has offices in four locations: headquarters in Washington, D.C.; staff offices at the CDC facility in Atlanta; and major laboratories in Morgantown, West Virginia and Cincinnati, Ohio. NIOSH staff are also assigned to PHS regional offices in Atlanta, Boston and Denver. An organizational chart for NIOSH is provided in Figure III-1.

**Databases and  
Grant Programs**

NIOSH maintains extensive databases of occupational safety and health information from around the world. NIOSHTIC is a computerized bibliographic database which contains over 120,000 citations with abstracts. Through a training grant program, NIOSH provides support to fourteen Educational Resource Centers (ERCs) and thirty Training Project Grantees located within colleges, universities and other institutions throughout the United States. These grantees offer academic and continuing education programs, perform research, and provide outreach efforts to industry, state health departments, and professional organizations and labor groups. NIOSH also offers direct short courses in the occupational safety and health field. For further information contact:

**Registrar**  
**NIOSH**  
4676 Columbia Parkway  
Cincinnati, Ohio 45226 - 1998  
(513) 533-8222.

**Project SHAPE**

A NIOSH initiative concerning engineering education is the Safety and Health Awareness for Preventive Engineering (SHAPE) project, which is the source of support behind the preparation of this instructional module on construction safety and health.

**NIOSH Headquarters**

Bldg. 1, Rm. 3007  
Centers for Disease Control  
and Prevention, 1600 Clifton —  
Rd. Atlanta, GA 30333  
(404) 639-3061

**NIOSH Washington Office**  
200 Independence Ave.S.W  
Washington, D.C. 20201  
(202) 472-7134

**-Appalachian Laboratories-**

944 Chestnut Ridge Rd. Morgantown, WY 26505-2888

**Div. of Respiratory  
Disease Studies**  
Studies of occupational  
respiratory diseases;  
mandated medical  
examination of coal  
miners (304) 291-4474

**Div. of Safety Research**  
Respirator certifications;  
Surveillance and studies to  
reduce musculoskeletal and  
traumatic work-related  
injuries and death  
(304) 284-5700

**Cincinnati Laboratories**

4676 Columbia Pkw Cincinnati, OH 45226-1998

**Robert A. Taft Laboratories**

**Div. of Biomedical &  
Behavioral Science**  
Laboratory and work site  
studies on toxicology,  
ergonomics, stress, and  
effects of physical agents  
(513) 533-8465

**Div. of Standards Develop.  
& Technology Transfer**  
NIOSH scientific policy  
development; clearinghouse  
of technical information on  
occupational safety  
and health (513) 533-8302

**Div. of Training & Manpower  
Development**, Training and  
education programs for OH&S  
personnel (513) 533-8821

**Alice Hamilton Laboratories**

**Div. of Physical Sciences &  
Engineering**  
Analytic support for  
research methods/equipment  
to control and measure  
occupational health hazards  
(513) 841-4321

**Div. of Surveillance, Hazard  
Evaluations & Field Studies**  
Surveillance and industry-  
wide studies; health hazard  
evaluations and technical  
assistance on request  
(513) 841-4428

**Figure III-1. Organization of NIOSH**

Project SHAPE encourages improvements in engineering practice, education and research through specific curriculum development efforts addressing the integration of occupational safety and health concepts in appropriate engineering design and professional courses. The primary audience is undergraduate engineering students. If engineering graduates receive basic knowledge in the occupational safety and health field, it is expected that they will have a direct long-term impact on the elimination of related problems in the workplace.

## **OTHER ORGANIZATIONS**

Besides OSHA (federal and state), OSHRC and NIOSH, there are numerous other organizations in the U.S. and abroad which directly or indirectly deal with construction safety and health. A majority of these are professional, industry or trade organizations representing the interests of their constituencies. A few are based in universities; and some are government or quasi-government agencies. A selective list of such organizations is presented in Table III-2. These organizations engage in a variety of activities, which include development of standards; research; development and distribution of printed and audio/visual resource materials; organization of committees, meetings, seminars and symposia; training programs; management of data bases; and technical assistance. Obviously, not all of these organizations deal with all aspects of construction safety and health.

## **Private Agencies**

There are also many private firms and industry groups which offer consultation services including training, or market safety equipment and related materials. In addition, insurance companies can offer excellent resources to assist their clients in safety and health related matters.

## **PRESENT STATUS OF SAFETY AND HEALTH LEGISLATION**

Two separate bills have been recently introduced in U.S. Congress; one focusing on the specific needs of workers in the construction industry, and another, a more comprehensive piece of legislation applicable to industry as a whole (including construction). First, the Construction Safety, Health and Education Bill was introduced in 1987, it has since been the subject of several hearings and substantial revisions. Second, the Comprehensive OSHA Reform Bill was introduced during 1991; it has also been the subject of several hearings. The two bills were later combined in the Senate. They have also been recently combined in both chambers of the Congress - H.R. 1280 and S.575.

## **Elements of the New Bill**

The current Construction Safety and Health Bill (Title XII of H.R. 1280 and S.575) contains five major elements (9). They are:

- 1) A required system of coordinated safety management and oversight on multi-employer construction projects;
- 2) Minimum requirements for contractor safety and health programs;
- 3) A direction for the establishment by OSHA of an effective system for targeting construction workplace inspections based on timely and accurate information;

**Table III-2**  
**Various Organizations Dealing with Construction Safety and Health**

American Society of Safety Engineers (ASSE) 1800 E. Oakton Street Des Plaines, IL 60018-2187	(708) 692-4121
National Safety Council (NSC) 444 Michigan Avenue Chicago, IL 66601	(312) 527-4800 (800) 621-7619
American National Standards Institute (ANSI) 1430 Broadway New York, N.Y. 10018	(212) 642-4948
National Institute for Standards and Technology (NIST)- (formerly National Bureau of Standards) Building Research, Rm B 216 Gaithersburg, MD 20899	(201) 975-5900
American Building Contractors, Inc. (ABC) 729 15th Street, N.W. Washington, D.C.	(202) 637-8800
Associated General Contractors of America, Inc. (AGC) 1957 E. Street, N.W. Washington, D.C. 20006	(202) 393-2040
National Constructors Association (NCA) 1101 15th Street, N.W. Suite 1000 Washington, D.C. 20005	(202) 223-1510
Business Round Table 1615 L Street, N.W. Suite 1100 Washington, D.C. 20036	(202) 872-1260
Construction Industry Institute (CII) The University of Texas at Austin 3208 Red River, Suite 300 Austin, TX 78705-2605	(512) 471-4319
Building and Construction Trades Dept. AFL/CIO 815 16th Street Washington, D.C. 20006	(202) 347-1416
Bureau of National Affairs (BNA) 1231 25th Street, N.W. Washington, D.C.	(800) 452-7773
American Society of Civil Engineers (ASCE) 345 East 47th Street New York, NY 10017-2398	(212) 705-7496
American Concrete Institute (ACI) Box 19150/Redford Station 22400 West 7 Mile Road Detroit, MI 48219	(313) 532-2600
American Institute of Architects (AIA) 1735 New York Avenue, N.W. Washington, D.C. 20006	(202) 626-7300
American Society for Testing and Materials (ASTM) 1916 Race Street Philadelphia, PA 19103	(215) 299-5400
National Society of Professional Engineers (NSPE) 1420 King Street Alexandria, VA 22314	(703) 684-2800
U.S. Environmental Protection Agency Waterside Mall 401 M. Street, S.W. Washington, D.C. 20460	(202) 382-2090

Table III-2 (Continued)

American Insurance Service Group, Inc. (AISG) 85 John Street New York, N.Y. 10038	(212) 669-0400
Center for Excellence in Construction Safety (CECS) West Virginia University Extension Service P.O. Box 6031 Morgantown, WV 26506	(304) 293-6142
World Safety Organization (WSO) 305 East Market Street P.O. Box 518 Warrensburg, MO 64093	(816) 747-3132
International Loss Control Inst. (ILCI) P.O. Box 345 Loganville, GA 30249	
Construction Safety Association of Ontario (CSAO) 74 Victoria Street Toronto, Ontario M5C2A5, CANADA	(415) 366-1501
Health and Safety Executive (HSE) Headquarters, Health & Safety Comm. Baynards House 7 Chepstow Place, Westbourne Grove London W2 4TF, U.K.	(071) 243-6000
American Consulting Engineers Council 1015 15th Street, N.W. # 802 Washington, D.C. 20005	(202) 347-7474
American Council for Construction Education 901 Hudson Lane Munroe, LA 70201	(318) 323-2413
American Institute of Steel Construction 400 N. Michigan Avenue Chicago, IL 60611-4185	(312) 670-2400
American Subcontractor's Association 1004 Duke Street Alexandria, VA 22314	(703) 684-3450
Association of Federal Safety & Health Professionals 7549 Wilhelm Drive Lanham, MD 20706-3737	(301) 552-2104
Associated Specialty Contractors 7315 Wisconsin Avenue Bethesda, MD 20814	(301) 657-3110
Construction Industry & Manufacturers Association 111 E. Wisconsin Avenue Milwaukee, WI 53202	(414) 272-0943
Construction Management Association of America 12355 Sunrise Valley Drive Suite # 640 Reston, VA 22091	(703) 391-1200
Construction Specification Institute 601 Madison Street Alexandria, VA 22314-1791	(703) 684-0300
National Erectors Association 1505 Lee Highway, Suite # 202 Arlington, VA 22209	(703) 524-3336
International Brotherhood of Electrical Workers 1125 15th Street, N.W. Washington, D.C. 20005	(202) 728-6137

- 4) Development of a cadre of OSHA compliance officers with experience in the construction industry and special training in construction safety and health; and
- 5) Establishment at OSHA headquarters of a new Office of Construction Safety, Health and Education, and the position of a Deputy Assistant Secretary for Construction to assure the existence of a coherent safety program for owners. This office would also deal with role definitions of safety responsibilities in the construction industry, and proper coordination among the Agency's offices and directorates and the Advisory Committee on Construction Safety and Health.

Of these five major elements, the first is probably the most significant because it represents a new legislative approach.

### REVIEW QUESTIONS

1. What is the significance of the Pittsburgh study in the historical development of safety and health legislation in the United States?
2. What were the basis and rationale for the OSH Act of 1970? What are the main provisions of the Act?
3. Describe the roles of OSHA, OSHRC, NIOSH and the states in dealing with the occupational safety and health problems in the U.S.
4. What are OSHA's inspection priorities? What types of violations of the OSH Act are considered by the compliance officers in OSHA inspections of construction projects?
5. What are the main functions of OSHA's new Office of Construction and Engineering?
6. Briefly describe NIOSH databases and grant programs. What are the objectives of the SHAPE project?
7. Name some important national and international professional and trade organizations which can serve as valuable resources to the civil engineer in safety and health related matters.
8. Describe the legislative trends in construction safety and health.

### REFERENCES

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2. Lubove, R.: Workmen's Compensation and the Prerogatives of Voluntarism, Labor History, Vol.8, No.3, pp.254 - 279 (Fall 1967).

3. U.S. Department of Labor: All About OSHA, OSHA 2056, Occupational Safety and Health Administration, Washington D.C. (1994).
4. Peyton, R.X., and T.C. Rubio: Construction Safety Practices and Principles, Van Nostrand Reinhold, New York, NY (1991).
5. Bowles, Jr., J.L.: Realities of OSHA Enforcement for Consulting Engineers - An ACEC Guide to Construction Site Safety, American Consulting Engineers Council, Washington, D.C. (1990).
6. U.S. Department of Labor: OSHA Reference Book, OSHA 3081, Occupational Safety and Health Administration, Washington D.C. (1985).
7. U.S. Department of Labor: Consultation Services for the Employer, OSHA 3047, Occupational Safety and Health Administration, Washington, D.C. (1985).
8. U.S. Department of Labor, Occupational Safety and Health Administration: Office of Construction and Engineering, Organization Staffing and Accomplishments; prepared for Advisory Committee on Construction Safety and Health (1992).
9. Lapping, J.E., and E.I. Leifer: The Need for New Federal Legislation to Promote Better Safety and Health Conditions of Construction Workers, EXCEL, Vol.6, No.283, Center for Excellence in Construction Safety, West Virginia University, Morgantown, WV (Summer 1993).

**UNIT IV**  
**ACCIDENT INVESTIGATION AND ANALYSIS, AND INJURY CONTROL**  
**FUNDAMENTALS**

**PURPOSE**

To summarize the principles governing accident investigation and analysis, and the identification, prevention and control of the hazards causing construction accidents and injuries.

**OBJECTIVES**

To familiarize the civil engineering student with:

1. Definitions of accident, hazard, risk, safety, and safety engineering
2. Causes of accidents in terms of unsafe acts and unsafe conditions
3. Accident/injury causation theories
4. Accident investigation, reporting and record keeping
5. Accident/injury prevention and hazard control.

**KEY TERMS**

Accident; hazard; risk; safety; safety engineering; unsafe acts; unsafe conditions; domino theory; behavioral models; management models; epidemiology; ergonomics; systems safety; fault tree analysis; energy theory; multiple factor theories; accident investigation; accident report; record keeping; injury prevention; hazard control; agent; vector; host; hierarchy of controls; barriers.

# UNIT IV

## ACCIDENT INVESTIGATION AND ANALYSIS, AND INJURY CONTROL

### FUNDAMENTALS

#### DEFINITION OF ACCIDENT

The dictionary defines an accident as "a happening or event that is not expected, foreseen or intended". In terms of its effects, it can also be defined as "an unexpected, unforeseen or unintended event which has a probability of causing personal injury or property damage." For the construction industry, an accident may be defined as "any event which interrupts the work process, caused by a combination of human, situational or environmental factors, which may result in personal injury, death, property damage, and other undesirable events". It should be noted that the use of the term accident in this module does not imply that construction accidents are unforeseen and unpredictable; neither does it imply a "no-fault" situation.

#### HAZARD, RISK, SAFETY AND SAFETY ENGINEERING

Other terms related to accidents include hazard, risk, safety, and safety engineering. According to Brauer (1), a hazard is "a condition with the potential of causing or contributing to an accident or illness." Risk is "a measure of both the likelihood and the consequences of all hazards of an activity or condition". Safety is "the state of being relatively free from harm, danger, injury or damage". Safety engineering is "the application of engineering principles to the recognition and control of hazards".

#### CAUSES OF ACCIDENTS

All accidents, injuries and illnesses can be attributed to one or more identifiable causes. Chance may play a role in bringing the causes together. It is generally agreed that accidents are caused by unsafe acts or unsafe conditions, or a combination of unsafe acts and unsafe conditions. Heinrich in the 1920's studied 75,000 accidents and established his well-known 88:10:2 ratio. He suggested that 88 percent of the accidents were caused by unsafe acts, 10 percent from unsafe conditions, and 2 percent were unpreventable (acts of God). Later studies, however, indicated that most accidents can be characterized as having resulted from a combination of unsafe acts and unsafe conditions (2). This is shown in Table IV-1.

Table IV-1  
Estimated Percentages of Accidents Due to Unsafe Acts versus  
Unsafe Conditions (2)

Study	% due to unsafe acts	% due to unsafe cond.	% due to combination	% unknown
Furniss.....	-	16	84	-
Pennsylvania Dept. of Labor.....	2	3	95	-
National Safety Council..	19	18	63	-
Mintz and Blum.....	21	-	79	-
Hagglund <sup>a</sup> .....	26	58	2	13
Hagglund <sup>b</sup> .....	35	54	4	7
Heinrich <sup>c</sup> .....	88	10	-	-

a Investigations of reported fatalities.

b Random sample of accident reports.

c Heinrich classified 2 percent as "unpreventable".

## **Unsafe Acts and Conditions**

### **Unsafe Acts in Construction**

For a given activity or project it is possible to identify the probable unsafe acts and unsafe conditions. Some of the unsafe acts in a construction environment are:

- . Operating tools and equipment without authority;
- . Using improper/defective/hazardous tools, equipment, materials, or vehicles;
- . Using tools, equipment, materials or vehicles in an unsafe fashion (not following safe procedures);
- . Failure to use personal protective equipment (PPE) and other gear provided to perform the job safely;
- . Making safety devices inoperative;
- . Failure to keep warning signs and labels;
- . Unsafe positioning, loading, placing, mixing, lifting and carrying;
- . Poor housekeeping;
- . Poor attitude (distraction, teasing, horseplay, substance abuse, etc.);

### **Unsafe Conditions in Construction**

Among the unsafe conditions which might exist in a construction environment, one can list:

- . Presence of unguarded, improperly or inadequately guarded, or otherwise defective tools, equipment and materials;
- . Poorly arranged site, materials and equipment;
- . Improper dress;
- . Improper ventilation and/or illumination;
- . Unsafe design and construction;
- . Lack of adequate training;
- . Physiological or psychological limitations of the employees;
- . Weather extremes (hot, cold, windy, wet, etc.);
- . Lack of effective safety management efforts and programs; and
- . Failure to provide personal protective and other equipment to perform work safely.

### **Engineers' Role**

It should be clear that both unsafe acts and unsafe conditions usually contribute to the occurrence of accidents. Engineers have many opportunities to eliminate or minimize the unsafe acts and conditions through their role in design, management and training.

## **ACCIDENT THEORIES**

There are several theories about accidents providing insight into causal factors and preventive actions. Naturally, none of these theories are entirely adequate in covering all pertinent factors contributing to the occurrence of accidents or predicting their likelihood. Depending on the point of view, some may appear more plausible than others.

### **Domino Theory**

An early theory for accident/injury causation was Heinrich's domino theory, which models an accident as a series of factors built like dominos as shown in Figure IV-1. The idea here was that any one domino can knock others over, culminating in injury. According to this theory:

- 1) Injuries are caused by accidents;

- 2) Accidents are caused by unsafe acts and unsafe conditions;
- 3) Unsafe acts are caused by faults of persons; and
- 4) Faults of persons are created by the social environment, or acquired through inheritance.

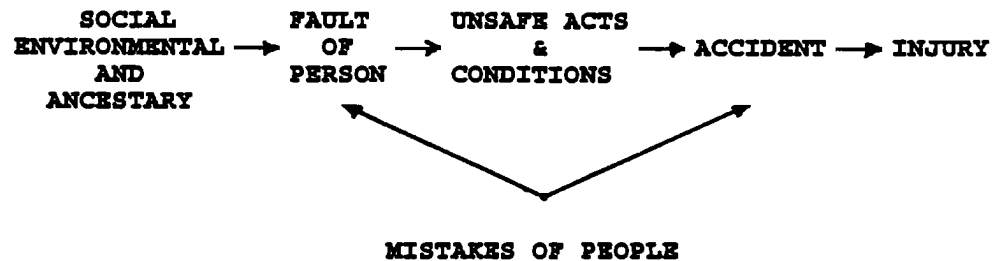


Figure IV-1. Heinrich's Domino Theory (2)

*Person Based Approach*

The most important domino in this approach is the one which relates to unsafe acts and conditions (but particularly to unsafe acts) which results from person-based factors. It should be noted that the Domino theory has lost its popularity with the advent of the newer, more complex accident/injury causation models.

**Behavioral Models**

Many safety specialists have emphasized the behavioral side of accident/injury causation, referring to the "accident proneness" of certain individuals (3). Efforts were made to identify such workers and either release them or not hire them in the first place. In later studies however, it was to reliably predict which workers are really injury prone. Yet, the belief still holds in many circles.

**Motivational Factors**

Other behavioral models have considered motivational factors and rewards for safety. However, there is some controversy over whether workers perceive positive rewards for working safely (4).

*Attitude*

According to Ferry (5), most unsafe acts can be attributed to the worker's attitude and to lack of knowledge or skill. Even after training to correct skill deficiencies, there is still the matter of attitude. Based on worker behavior, it may be possible to list several characteristics of poor attitude. These are:

*Characteristics of Poor Attitude*

- . Poor work habits
- . Indifference
- . Daring acts

- . Laziness
- . Haste
- . Temper
- . Following poor examples
- . Perfectionism
- . Boredom
- . Self-destructive action
- . Peer-destructive action
- . Superiority
- . Inferiority, and
- . Paranoia.

### **Management Models**

These models utilize a modified version of the domino theory, shifting the emphasis from the worker as the cause of the injuries to the management system in which the worker exists (6). The domino effects in this case are as follows:

#### *Modified Domino Effects*

- 1) Injuries are caused by accidents.
- 2) For each accident, there are immediate causes that are symptomatic of problems in the overall system.
- 3) There are basic causes in the overall management of the system that produce the immediate causes of the accident.
- 4) The lack of management control permits the basic causes of accidents to exist in the system.

### *Factors Causing Management Failure*

Ferry (5) has listed the following basic mishap causal factors traceable to management failure:

- . Poor housekeeping
- . Improper use of tools, equipment, and facilities
- . Unsafe or defective equipment and facilities
- . Lack of proper procedures
- . Unsafe improvised procedures
- . Failure to follow prescribed procedures
- . Job not understood
- . Lack of awareness of hazards involved
- . Lack of proper tools, equipment, and facilities
- . Lack of guards and safety devices
- . Lack of protective clothing and equipment
- . Exceeding prescribed limits, loads, speed, strength, and so on
- . Inattention, neglect of safe practices
- . Fatigue and reduced alertness
- . Misconduct, poor attitude.

### **Epidemiologic Models**

Epidemiology is the science which deals with the search for causal association between diseases or other biological processes and specific environmental experiences or exposures. The epidemiologic model applied to injury research seeks to explain the occurrence of injuries within the system of host (injured victim), agent (means of injury) and environment (physical, psychological, and social factors related to the

event). This model recognizes the interactive nature of the injury process and requires a large amount of information to be collected on the host, the agent, the environment, and the interactions between these (2).

#### *Common Features of Accidents*

Using such a model, it should be possible to identify features common to a set of injuries and accidents, and identify causes. This approach is better than looking at each accident independently. Through this approach of collective study, it may be possible, for instance, to associate a group of accidents with a company's particular processes or products.

#### **Ergonomic Models**

Neither workers, nor machines, nor workplaces exist apart from each other. To accomplish work all must come together, and injuries and illnesses sometimes result from their interactions. The study of these interactions is called "ergonomics", or "human factors engineering". This discipline is an applied science concerned with the design of facilities, equipment, tools, and tasks that are compatible with the anatomical, physiological, biochemical, perceptual, and behavioral characteristics of humans. The principle behind ergonomics design is that the machine should fit the worker rather than forcing the worker to fit the machine. The objective is safety, effectiveness, and efficiency wherever people are part of a system.

#### *Focus on Task Design*

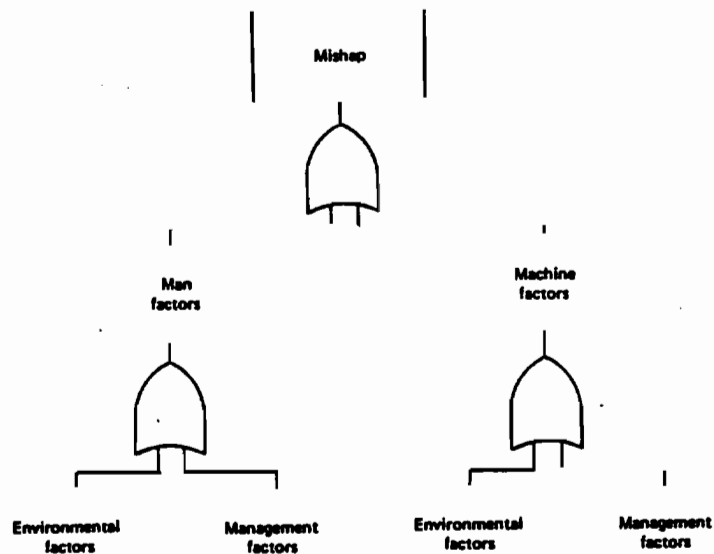
The injury causation models developed by ergonomists attempt to provide insights into problems of "unsafe acts" or human error, which are lacking in other models. Rather than viewing operators' errors as merely "unsafe acts" that can only be addressed through training and motivation, the ergonomics approach looks carefully at the machine features, or the design of the work, to see if they contributed to the workers errors (2). In addition, ergonomists analyze the physical capacities of workers, such as lifting or reaching ability, to determine whether the task places undue stress on specified parts of the body, or leads to excessive fatigue. The focus then is on designing the work task, rather than installing machinery, and letting the worker find a way to adapt. The principal shortcoming of the ergonomic model is the absence of any analysis of hardware failures beyond the human/machine interface.

#### **Systems Safety Models**

The system safety models have been extensively used to analyze failures in systems hardware and equipment. They focus on the human element to a lesser degree. These models utilize a "network" of components attempting to identify the critical system/subsystem components, progressive failure modes and probabilities of failure. Several techniques may be used in systems safety analysis (5). These include failure mode and effect analysis (FMEA), technique for human error rate prediction (THERP), and fault tree analysis (FTA).

### *Fault Tree Analysis*

The widely used fault-tree analysis is based on a symbolic logic diagram that shows the cause-and-effect relationships between an undesirable event and one or more contributing causes. Beginning with a mishap or failure (top event) the contributory events are traced backward in a tree-like network until completely independent events (causal factors) are reached. A conceptual fault tree diagram illustrating the contributions of the man, machine, environmental and management factors to a mishap is presented in Figure IV-2 (5).



**Figure IV-2. Conceptual Fault Tree Diagram (5)**

### *Use of Computers*

Computers, with the right software, make it possible to process large amounts of information by the various techniques of systems safety analysis. A detailed coverage of the techniques and software are outside the scope of this module. Excellent information on related topics can be found in references (1), (5), and (6).

### **Energy Theory**

Haddon (8) proposed the idea that many accidents and injuries involve the transfer, or release, of energy which must be controlled for the prevention of mishaps. This theory suggests that quantities of energy, means of energy transfer and rates of transfer are related to the kind and severity of injuries. Depending on the case, safety engineers can focus

### *Types of Energy*

on:

- . Mechanical energy (structural loads, noise and vibration, friction, tools and machines, fluid pressure, motor vehicles);
- . Electrical energy (power shock, heat, arcing);
- . Thermal energy (fire, heat and cold, expansion, explosion);
- . Chemical energy (hazardous materials, gases, fumes); and
- . Radiation (ionizing and non-ionizing).

It is also possible to add bio-hazards (bacterial, fungal, parasitic, rickettsial and viral) to this list.

### **Multiple Factor Theories**

In this approach, it is suggested that multiple factors combine in a random or other fashion to cause accidents and injuries. Multiple factor theories help identify which characteristics of the considered factors are involved so that possible critical combinations can be analyzed by qualitative and/or quantitative techniques. A specific case of the multiple factor theories is the 4M model (9), referring to MAN, MACHINE, MEDIA, and MANAGEMENT. These factors can be described by a set of characteristics. For example, age, height, gender, skill level, and motivation could be the characteristics associated with man. Temperature, humidity, and contaminants in air could be the media characteristics. Machine characteristics could include size, shape, energy source, and type of motion. Management characteristics might be management style, organizational structure, communication system, policy and procedures. Each of these factors can be analyzed singly or in combination to identify the cause of a related accident or injury.

### **ACCIDENT INJURY RELATIONSHIPS**

The question of what proportion of accidents result in injury has been addressed by a number of researchers (1). Heinrich's early studies yielded a 300:29:1 ratio, indicating that for every group of 330 accidents of the same kind, 300 result in no injuries, 29 produce minor injuries, and 1 results in a major, lost-time injury. Bird and Germain (10) later reported a ratio of 500:100:1 for property-damage (only) accidents, minor-injury accidents, and disabling-injury accidents. Other studies by Fletcher (11) showed a 175:19:1 for no-injury, minor-injury, and serious-injury accidents. These relationships show that many accidents do not result in major injury. They further indicate that as the severity of accidents increases, the frequency of major injury cases decreases.

### **ACCIDENT INVESTIGATION**

Every accident, including those which do not result in serious injury or property damage, should be investigated. In industrial accidents, this can be accomplished by the supervisor/foreman, line manager, safety professional, a special committee, or a consultant (5). The results of accident investigations should be documented in a report. The information gathered in this process can be analyzed to:

#### **Purpose of Accident Reports**

- . Identify the principal causes (materials, machines, methods);
- . Assess the degree of damage and the value of losses;
- . Reveal the size of the accident problem relative to different

- departments of a company and among various occupations;
- . Indicate the possible need for engineering revision by identifying unsafe equipment and materials;
- . Disclose inefficiencies in operating processes and procedures;
- . Reveal unsafe practices which call for employee training;
- . Reveal improper placement of personnel;
- . Provide supervisors with essential and timely information about accidents; and
- . Permit an objective evaluation of the progress of a particular safety program adopted by the company.

Accident investigations also produce data serving as legal or liability evidence to be used in the event of insurance claims or lawsuits.

### **Accident Investigations Leading to Preventive Measures**

The injury causation models previously described can be used as bases for accident investigation and analysis. Accident investigation and analysis, used as a preventive measure for future accidents, aims at producing complete, meaningful and specific information about the causes. Merely obtaining the information will not prevent the recurrence of accidents. Appropriate action must be taken to correct deficiencies and to provide the necessary training. Accident investigations must be "fact finding" rather than "fault finding". Fairness and impartiality are essential.

### **Record Keeping**

A good record-keeping system is essential to the success of an accident investigation. Keeping records and reporting of work-related accidents are required by law. OSHA requires that each employer having eleven or more employees must maintain a log of recordable occupational injuries and illnesses and an annual summary by calendar year. In addition, a more detailed supplementary record must be made of each recordable occupational injury or illness. Recordable cases include every occupational death, occupational illness and occupational injury involving loss of consciousness, restriction of work or motion, transfer to another job, or medical treatment (which does not include first aid). Figure IV-3 shows a decision chart for determining whether a case is recordable.

### **OSHA Accident Reporting Forms**

Samples of the OSHA 200 form (Log and Summary of Occupational Injuries and Illnesses) and the OSHA 101 form (Supplemental Record of Occupational Injuries and Illnesses) are presented in Figure IV-4 and Figure IV-5, respectively. Such records must be available for inspection and submitted to the Bureau of Labor Statistics upon request. If an employee is killed on the job, or if five or more employees are hospitalized or killed in an accident, the employer must report the accident to OSHA within 8 hours. These records must be maintained for a period of not less than five years following the end of the year to which they relate.

### **Company Accident Investigation Forms**

Note that the OSHA 101 form essentially represents an individual accident report. However, some companies prefer to generate more detailed reports of their accident investigations.

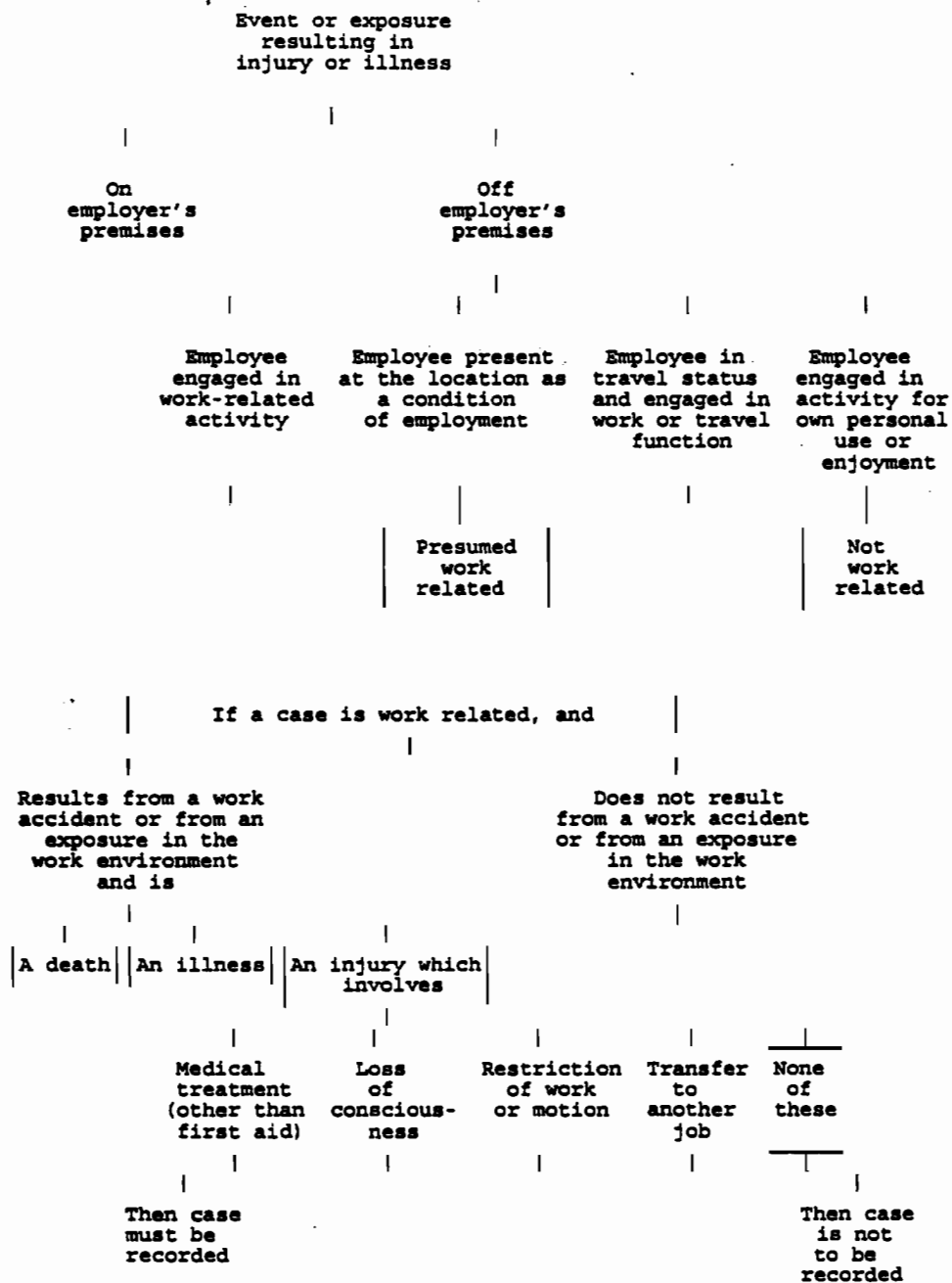


Figure IV-3. Guide to recordability of cases under the Occupational Safety and Health Act

Bureau of Labor Statistics  
Log and Summary of Occupational  
Injuries and Illnesses

**NOTE:** This form is required by Public Law 91-606 and must be kept in the establishment for 3 years. Failure to maintain and post can result in the issuance of citations and assessment of penalties. (See posting requirements on the other side of form.)

**RECORDABLE CASES:** You are required to record information about every occupational death; every nonfatal occupational illness; and those nonfatal occupational injuries which involve one or more of the following: loss of consciousness, restriction of work or motion, transfer to another job, or medical treatment (other than first aid). (See definitions on the other side of form.)

Case or File Number	Date of Injury or Onset of Illness	Employee's Name	Occupation	Department	Description of Injury or Illness
Enter a nonduplicating number which will facilitate comparisons with supplementary records.	Enter Mo./day.	Enter first name or initial, middle initial, last name.	Enter regular job title, not activity employee was performing when injured or at onset of illness. In the absence of a formal title, enter a brief description of the employee's duties.	Enter department in which the employee is regularly employed or a description of normal workplace to which employee is assigned, even though temporarily working in another department at the time of injury or illness.	Enter a brief description of the injury or illness and indicate the part or parts of body affected.  Typical entries for this column might be: Amputation of 1st joint right forefinger; Sprain of lower back; Contact dermatitis on both hands; Electrocution—body.
(A)	(B)	(C)	(D)	(E)	(F)
					PREVIOUS PAGE TOTALS →

OSHA No. 200

Figure IV-4. OSHA No. 200 Form: Annual Summary of Occupational Injuries and Illnesses

U.S. Department of Labor

For Calendar Year 19 \_\_\_\_\_

Page \_\_\_\_\_ of \_\_\_\_\_



Company Name  
Establishment Name  
Establishment Address

Form Approved  
O.M.B. No. 1220-0029  
See OMB Disclosure  
Statement on reverse.

Extent of and Outcome of INJURY

Type, Extent of, and Outcome of ILLNESS

Nonfatal Injuries						Nonfatal Illnesses												
Injuries With Lost Workdays						Illnesses With Lost Workdays												
Injury Without Lost Workdays						Illness Without Lost Workdays												
Enter DATE of death.	Enter a CHECK if injury involves days away from work, or days of restricted work activity, or both.	Enter a CHECK if injury involves days away from work.	Enter number of DAYS away from work.	Enter number of DAYS of restricted work activity.	Enter a CHECK if no entry was made in columns 1 or 2 but the injury is reportable as defined above.	CHECK Only One Column for Each Illness (Use other side of form for combinations or permanent conditions.)							Enter DATE of death.	Enter a CHECK if illness involves days away from work, or days of restricted work activity, or both.	Enter a CHECK if illness involves days away from work.	Enter number of DAYS away from work.	Enter number of DAYS of restricted work activity.	Enter a CHECK if no entry was made in columns 8 or 9.
(1)	(2)	(3)	(4)	(5)	(6)	(a) Occupational skin diseases or disorders	(b) Dust diseases of the lungs	(c) Respiratory conditions due to toxic agents	(d) Poisoning (systemic or local)	(e) Disorders due to physical agents	(f) Disorders associated with repeated trauma	(g) All other occupational illnesses	(8)	(9)	(10)	(11)	(12)	(13)

INJURIES

ILLNESSES

Certification of Annual Summary Totals By \_\_\_\_\_

Title \_\_\_\_\_

Date \_\_\_\_\_

OSHA No. 200

POST ONLY THIS PORTION OF THE LAST PAGE NO LATER THAN FEBRUARY 1.

Figure IV-4. (Continued)

Bureau of Labor Statistics  
Supplementary Record of  
Occupational Injuries and Illnesses

U.S. Department of Labor



This form is required by Public Law 91-596 and must be kept in the establishment for 5 years. Failure to maintain can result in the issuance of citations and assessment of penalties.

Case or File No.

Form Approved  
O.M.B. No. 1220-0029

Employer

1. Name
2. Mail address (No. and street, city or town, State, and zip code)
3. Location, if different from mail address

See OMB Disclosure  
Statement on reverse

Injured or Ill Employee

4. Name (First, middle, and last)
5. Home address (No. and street, city or town, State, and zip code)
6. Age
7. Sex: (Check one)  
Male ☐ Female ☐
8. Occupation (Enter regular job title, not the specific activity he was performing at time of injury.)
9. Department (Enter name of department or division in which the injured person is regularly employed, even though he may have been temporarily working in another department at the time of injury.)

Social Security No.

The Accident or Exposure to Occupational Illness

If accident or exposure occurred on employer's premises, give address of plant or establishment in which it occurred. Do not indicate department or division within the plant or establishment. If accident occurred outside employer's premises at an identifiable address, give that address. If it occurred on a public highway or at any other place which cannot be identified by number and street, please provide place references locating the place of injury as accurately as possible.

10. Place of accident or exposure (No. and street, city or town, State, and zip code)
11. Was place of accident or exposure on employer's premises? Yes ☐ No ☐
12. What was the employee doing when injured? (Be specific. If he was using tools or equipment or handling material, name them and tell what he was doing with them.)
13. How did the accident occur? (Describe fully the events which resulted in the injury or occupational illness. Tell what happened and how it happened. Name any objects or substances involved and tell how they were involved. Give full details on all factors which led or contributed to the accident. Use separate sheet for additional space.)

Occupational Injury or Occupational Illness

14. Describe the injury or illness in detail and indicate the part of body affected. (E.g., amputation of right index finger at second joint; fracture of ribs; lead poisoning; dermatitis of left hand, etc.)
15. Name the object or substance which directly injured the employee. (For example, the machine or thing he struck against or which struck him; the vapor or poison he inhaled or swallowed; the chemical or radiation which irritated his skin; or in cases of strains, hernias, etc., the thing he was lifting, pulling, etc.)

16. Date of injury or initial diagnosis of occupational illness
17. Did employee die? (Check one) Yes ☐ No ☐

Other

18. Name and address of physician
19. If hospitalized, name and address of hospital

Date of report

Prepared by

Official position

OSHA No. 101 (Feb. 1981)

Figure IV-5. OSHA No. 101 Form : Supplemental Record of Injuries and Illnesses

An example of a comprehensive accident investigation report is provided in Figure IV-6.

#### **Steps of Investigation**

An accident investigation may be conducted by the supervisor or foreman, by the safety professional of the company, by the project safety committee, by an investigative committee or by an independent consultant. Ferry (5) has illustrated the accident investigation process in twelve ascending steps as shown in Figure IV-7. It is clear that a complete investigation involves preparation for the investigation; performing the investigation; taking action to correct the situation; and critiquing the investigation to ensure that the process is continually improved. Elements of this process are included in the example accident report form presented in Figure IV-6.

#### **ACCIDENT AND INJURY PREVENTION**

Information gathered and lessons learned from past accidents can be integrated in preventive strategies to eliminate or minimize the risks for future mishaps of similar nature. A better strategy, perhaps, is the analysis of "near-misses", or potential accidents, so future accidents can be prevented before any accident occurs for the first time. An accident prevention program can focus on frequency, severity, or cost, singly or in combination, and try to direct the preventive efforts toward the critical accident or injury types as judged by these factors.

#### **Hazard Control**

In order to eliminate or minimize hazards, one must be able to:

- . Recognize the hazards;
- . Define and select preventive actions;
- . Assign responsibilities for implementation; and
- . Monitor the effectiveness of preventive actions.

#### **Abnormal Energy Transfer**

Based on Haddon's energy theory, one can consider injuries to be caused by abnormal energy transfers or interferences with energy transfer. An injury causing event can thus be broken down to three components:

- 1) The source of hazard (agent);
- 2) The transmission of hazard (vector); and
- 3) The worker (host).

#### **Control Technologies**

Control technologies suggested by this approach should consequently consider:

- . Control at the source of energy;
- . Control of transmission of energy; and
- . Control at the worker.

For example, control of electrical energy at the source may involve proper grounding. Control of transmission could include separating the worker from the hazard by placing barriers or guards between the hazard and the worker. Personal protective equipment, such as insulated gloves, represents a control applied on the worker.

## Accident Investigation Report

### Instructions to Supervisor/Investigator:

Please complete this form within 48 hours of the incident. Attach to this report any pictures police report, or witness statements. Make copy for the injured person, for your file, and forward original to management.

Be accurate and use factual information only. Type or use black ink.

Copy Requested:        Yes...        No...

Copy Requested:

By:

Date:

Date Sent:

By:

Date:

Date Sent:

### Agency or Company Information

1. Dept. Code .....
2. Main Office/Headquarter File No. ....
3. Original = 1  
Revision = 2
4. Your Office OSHA Case # ..... Injury = 1, Illness = 2
5. Is injured person a visitor to the site or a worker,  
visitor = 1, worker = 2
6. Total Employees Injured .....: Fill Report For Each.
7. Minor Yes = 1, No = 2

### General Information

8. Date of Accident ....
9. Day of Week .....
10. Time of Accident ..... AM = A, PM = P
11. Exact Location of Accident
12. Date Reported to Supv. Month/day/year/ ....
13. Date of Report ....
14. Date This Report Send to Management .....  
Hand Delivered = H, Mailed = M
15. Contractor's Name  
General = 1        Sub-contractor = 2  
Contract # ..... , Type of Construction .....  
Type of Work: Civil = 1, Military = 2

### Personal Data

16. Name of Injured person: First, Initial, Last  
.....  
Home phone #:  
Social Security #:  
Home Address:  
17. Sex: Male = M, Female = F
18. Birthday ....
19. Married = M, Single = S, Divorced = D, # of Children .....
20. Education, Specify ...  
Any safety courses: Type & Duration ...
21. Job Title  
Experience in type of work he/she was doing at time of accident,  
# of months ....  
How long with this agency/company .....
22. Any previous accident he/she has been involved in  
Yes = 1 No = 2 If Yes specify when and how.

Figure IV-6. Example Accident Investigation Report Form

Manager/Supervisor

24. Name of Supervisor  
Home phone # ( ) .....  
Social security ....  
Home address:  
Work address:  
25. Completed safety management course ?  
Yes = 1 No = 2 if Yes specify type and duration ...  
26. History of accidents on supervisor's job sites.  
How many = Minor = M, .... Total = F ....

OSHA Information

27. Hospital Yes = 1 No = 2 Date: ... ..  
Name & Address:  
28. X- Rays taken Yes = 1 No = 2  
29. Doctor Yes = 1 No = 2 Date: ... ..  
30. Extent of injury (if death, notify Dept. of Labor within 8 hours) ...  
Date of death ... ..  
Where: On site = 1 Hospital = 2, Home = 3  
Date Dept. of Labor notified: ... ..  
31. Injured received medical treatment  
Yes = 1 No = 2  
32. Injured received First Aid only  
Yes = 1 No = 2  
33. Termination or permanent transfer?  
Yes = 1 No = 2  
34. Last day worked ... ..  
35. Date return to work ... ..  
36. Lost work days  
Estimate ..... Actual .....  
37. Lost work days restricted  
Estimate ..... Actual .....

Worker's compensation

38. Occupation (be specific) .....  
39. # hours regularly worked per week ....  
Ave. overtime hrs. ....  
40. Straight time hourly wage rate .....  
41. From payroll record- gross income for last 13 weeks .....  
Straight time total \$ .... # weeks .... Average \$ ....  
Overtime total \$ .... # weeks .... Average \$ ....  
Board & Room- value \$ .... Average per week \$ ....  
Combined average weekly earning \$ .....

Loss Control

42. Place of accident ( address with city & state ) ...  
43. Exact location of accident ( same as # 10 above, include picture of site ) ...  
44. Environmental conditions  
Weather ... , Avg. Temp ... , Housekeeping ...  
45. Physical characteristics ...  
46. Part of body (indicate area of injury; or attach figure).  
47. Source of personal injury ...  
48. Source of property damage ...  
49. Type of accident ...  
50. Activity engaged  
1= Authorized , 2= Unauthorized , 3= Other explain ...  
51. How long assigned Task ....  
52. Explain events of accident & describe injury ....  
53. Causal Factors ( why did it happen ) ....  
54. Opinion on major factor ....  
55. Unsafe  
Act = 1 , Condition = 2 ...  
56. Corrective actions-tell what has been done or planned, relate to each of # 55, 56 & 57  
Estimate time of completion of corrective action if not done yet.  
57. Completion of actions  
List # of actions and each one completed.

Figure IV-6. (Continued)

58. Attachment, Check 1 or more and # of pages.  
 A. Sketch, B = Photo, C. Statement/police report,  
 E. News release, F. Medical report, G. Additional pages,  
 H. Other ...
59. Employee signature:  
 Agree = 1 Disagree = 2 ...
60. Would this accident have caused one of the following:  
 A. Permanent disability .....  
 B. Death .....  
 C. Temp. disability & lost workday .....  
 D. Med. treatment, no lost work .....  
 E. First aid treatment .....
61. Was this accident preventable  
 1 = Preventable  
 2 = Non-preventable
62. Do you think this is a safe work place?  
 Yes = 1 No = 2  
 Your recommendation for achieving a safer job site .....

Investigated by

63. Investigator's signature .....  
 Supervisor's init. & date if not investigator.
64. Investigator (if other than supervisor)  
 Name:  
 Position:  
 Reason:  
 Date:
65. Reviewed by safety professional  
 Name:  
 Position:  
 Reason:  
 Date:
66. OSHA review (if any and their comments)  
 Name:  
 Position:  
 Reason:  
 Date:
67. Additional comments: .....

Loss resulted

68. Total cost (include medical, equipment, corrective action & other) .....
69. Were any law suits involved ?  
 Yes = 1 No = 2
70. Court judgement, describe: .....

Figure IV-6. (Continued)

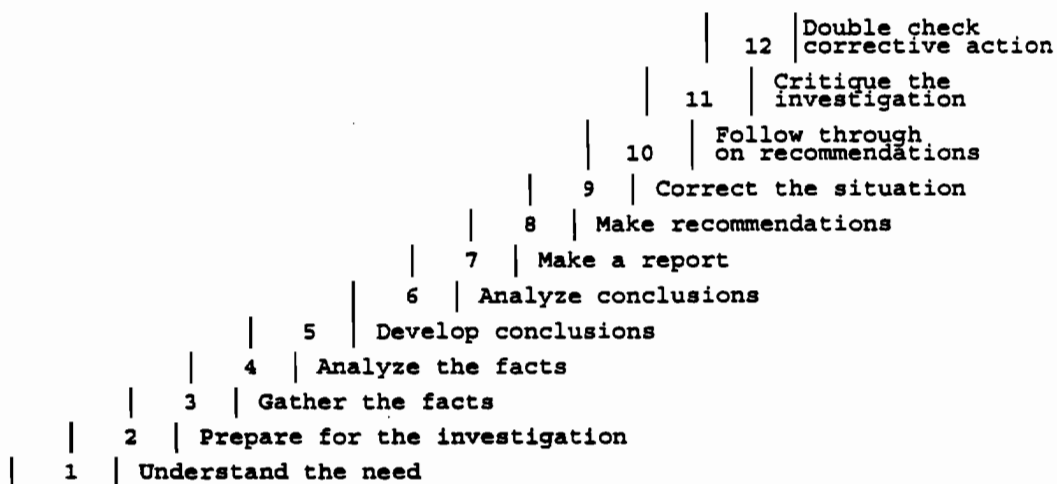


Figure IV-7. The twelve steps of investigation (5).

## **Hierarchy of Controls**

Hierarchy of controls describes the order that should be followed when choosing among options for controlling health and safety hazards. The concept has traditionally been considered more applicable to health hazards than safety hazards (2); however, it has been adopted by ANSI, OSHA and many safety organizations for the control of accident and injury hazards. The basic principle is to control the hazard as close to the source as possible. A priority system has been suggested in the National Safety Council's Accident Prevention Manual (12), which lists the following hierarchy:

### ***Eliminate***

1) Eliminate the hazard from the machine, method, material, or plant structure;

### ***Control***

2) Control the hazard by enclosing or guarding it at its source;

### ***Train***

3) Train personnel to be aware of the hazard and to follow safe job procedures to avoid it; and

### ***Prescribe PPE***

4) Prescribe personal protective equipment (PPE) for personnel to shield them against the hazard. Many industrial hygienists regard this type of control as a last resort, used as a back-up.

For a comprehensive discussion of the hierarchy of controls concept, including its advantages and limitations, please refer to reference (2).

## **Barriers in Hazard Control**

Hazard control principles can also be described by considering barriers. Barriers can be physical or human barriers. The physical barriers could be:

### ***Physical Barriers***

- . A barrier at the energy source; an example of this is de-energizing a circuit by use of a switch;
- . A barrier between the energy source and worker; examples are insulation of electrical conductors, grounding, safety nets, and pressure vessels;
- . A barrier on the worker; examples are respirators, safety harness and insulated gloves; and
- . A barrier of space or time between the energy source and the worker; an example for this could be requiring minimum distances between earth moving equipment.

### ***Human Barriers***

Human barriers, on the other hand, can be represented by the following:

- . Designing to eliminate hazards; an example is relocating utilities away from the construction site;
- . Macro work practices and procedures; an example is moving an assembled scaffolding by crane instead of constantly assembling and dismantling;
- . Rules, regulations and procedures; example, detailed task descriptions;
- . Management control and incentives; examples are enforcement of procedures by supervision and issuing penalties for non-compliance; and
- . Education and training; this could focus on hazard recognition, correct tool usage and use of personal protective equipment.

## REVIEW QUESTIONS

1. Define the terms accident, hazard, risk, safety and safety engineering.
2. What are some common unsafe acts and some common unsafe conditions in the construction environment? Give an example of how a combination of unsafe acts and unsafe conditions can cause a construction accident.
3. Describe Heinrich's domino theory. Why is it not so popular anymore?
4. Compare and contrast Heinrich's domino theory with the management models of accident/injury causation.
5. What are the essential features of behavioral models, epidemiologic models and ergonomic models?
6. What are the system safety models used for? What are some of the network analysis tools used in application of system safety?
7. How does fault tree analysis work? Describe by a conceptual example.
8. What is the basis of the energy theory? What are the different types of energies that may be involved in injury causation?
9. What is the multiple factor theory? What are its advantages? Describe the 4M model.
10. What are the purposes of accident investigations and accident reports?
11. Describe the main features of OSHA 200 and OSHA 101 forms. Why should companies have their own accident investigation and reporting forms?
12. List the twelve steps involved in an accident investigation, and discuss the rationale behind these steps.
13. Why should "near-misses" be investigated?
14. Explain the meaning of the terms agent, vector, and host in regard to abnormal energy transfer. Describe by examples the relevant hazard control technologies.
15. Describe the hierarchy of controls principle. Give an example.
16. Describe the physical and human barriers which can be employed for hazard control.

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**UNIT V**  
**CONSTRUCTION INDUSTRY SAFETY AND HEALTH PRACTICES AND APPLICABLE**  
**OSHA STANDARDS**

**PURPOSE**

To present an overview of the scope and nature of construction related hazards, and the standards and practices associated with their control:

**OBJECTIVES**

To familiarize the student with:

1. The specific hazards related to various construction activities and tasks.
2. The industry practices for hazard control.
3. Applicable OSHA standards.
4. The identification and control of the safety and health hazards specifically related to:
  - (a) Material handling;
  - (b) Welding and cutting;
  - (c) Concrete construction;
  - (d) Steel erection;
  - (e) Fall protection, ladders and scaffolds;
  - (f) Cranes, derricks and hoists;
  - (g) Heavy construction equipment;
  - (h) Motor vehicles;
  - (i) Hand and power tools;
  - (j) Electrical work;
  - (k) Excavation and trenching;
  - (l) Confined space entry; and
  - (m) Contaminated site cleanup.

**KEY TERMS**

Safety and health resources; OSHA standards; NIOSH Alerts; material handling; hazardous material; ignitable; corrosive; reactive; toxic; asphyxiant; carcinogen; mutagen; teratogen; asbestosis; silicosis; right-to-know laws; hazard communication standard; housekeeping; manual lifting; back injuries; NIOSH equation for weight limit; lifting index;

manual handling assist devices; rigging safety; welding and cutting hazards; welding equipment safety; personal protective equipment; concrete hazards; hazardous substances; formwork and shoring; striking or falling objects; rebar handling and installation; structural failures; concrete placement safety; shoring safety factor; cold weather precautions; steel erection; design hazard; erection safety; communications; fall prevention; fall protection; safety harness; lanyard; life line; anchor point; safety net; ladder safety; scaffolding safety; elevating work platforms; roofing safety; crane; derrick; hoist; mobile crane; tower crane; bridge crane; stability; heavy construction equipment; bulldozer; scraper; motor grader; front-end loader; motor vehicle safety; hand and power tools; manual tools; electric tool safety; sawing safety; powder actuated tool; training; electrical work; overhead and underground cables; receptacles; connectors; grounding; ground fault circuit interrupter (GFCI); excavation and trenching; cave-in; shoring systems; sloping; trench shield; inspection; competent person; confined space entry; oxygen deficiency; atmospheric hazards; permit-to-work system; monitoring; rescue; contaminated site cleanup; hazardous chemicals; biological hazard; radioactive hazard; physical hazard; site safety and health plan; hazard and safety training; medical program; site characterization; air monitoring; protective clothing; site control; decontamination; site emergencies.

## **UNIT V**

### **CONSTRUCTION INDUSTRY SAFETY AND HEALTH PRACTICES AND APPLICABLE OSHA STANDARDS**

#### **RESOURCES AND STANDARDS**

There are organized efforts in industry and government to prevent accidents, injuries and illnesses, and pertinent resources are available in the form of manuals, catalogs, pamphlets, videos, etc (1,2,3). These resources cover the principles of hazard recognition and control as applicable to various construction activities and tasks, and provide training on safe procedures and practices. Further, there exists a voluminous body of safety and health standards (4,5) enforced by OSHA which are updated periodically. States that have their own safety and health programs usually have their own version of the OSHA standards. The OSH Act requires that all employers and employees comply with the promulgated safety and health regulations and standards under the appropriate jurisdictions.

#### **OSHA Standards**

#### **NIOSH Alerts**

The National Institute for Occupational Safety and Health (NIOSH) has published a number of resource documents under the name NIOSH Alert, addressing the prevention of occupational injuries and fatalities in a variety of construction and/or other work practices. A listing of the available NIOSH Alerts is provided in Table V-I. These documents are also appended to this module in their entirety in an effort to disseminate the valuable information and recommendations contained therein (see APPENDIX). The NIOSH alerts typically cover:

- . Background information on fatality/injury causing occupational tasks;
- . Brief reports on relevant cases;
- . Appropriate and applicable regulations and standards;
- . Recommendations on procedures for hazard recognition, testing and evaluation, prevention, safe work practices, and rescue operations; and
- . References for further information on the subject.

#### **SCOPE OF THE UNIT**

The industry and government resources and OSHA standards are exhaustive; so, no attempt will be made to cover in this unit every possible aspect, and every detail. Instead, highlights are presented here that are considered to be important and representative. The reader is directed to the references listed in NIOSH Alert documents provided in the APPENDIX, and the references cited at the end of this unit for a more thorough coverage.

In the following sections of this unit, we present information on the recognition and control of safety and health hazards for material handling; welding and cutting; concrete construction; steel erection; fall protection; ladders and scaffolds; cranes, derricks and hoists; heavy construction equipment; motor vehicles; hand tools; electrical work;

excavation and trenching; confined space entry; and contaminated site cleanup. Applicable OSHA standards are cited for each case; however, no attempt is made to elaborate the specific details of these standards. The reader is directed to references (4) and (5) for details.

**Table V-1**  
**Listing of Available NIOSH Alerts**

<b>Title</b>	<b>Date</b>	<b>DHHS (NIOSH) Publ. No.</b>
1. Request for Assistance in Preventing Electrocutions Between Cranes and Power Lines	7/85	85-111
2. Request for Assistance in Preventing Occupational Fatalities in Confined Spaces	1/86	86-110
3. Request for Assistance in Preventing Fatalities of Workers Who Contact Electrical Energy	12/86	87-103
4. Request for Assistance in Preventing Electrocutions of Workers Using Portable Metal Ladders Near Overhead Power Lines	7/89	89-110
5. Request for Assistance in Preventing Deaths and Injuries from Falls Through Skylights and Roof Openings	12/89	90-100
6. Request for Assistance in Preventing Electrocutions During Work with Scaffolds Near Overhead Power Lines	8/91	91-110
7. Request for Assistance in Preventing Lead Poisoning in Construction Workers	4/92	91-116a
8. Request for Assistance in Preventing Worker Injuries and Deaths Caused by Falls From Suspension Scaffolds	8/92	92-108

## **MATERIAL HANDLING**

In the context of this module, the term material handling encompasses all activities associated with the transportation, receiving, storage, dispensing, and management of the construction and related materials on and off the jobsite. Materials themselves may be considered hazardous, or there may be hazards created by their improper handling. Dealing effectively with the various types of materials handled in construction projects requires understanding their hazards, and making effective planning and implementation decisions with regard to the mode of transport, time of delivery, quantity of materials, and allocation of safe and suitable storage space.

### **Hazardous Materials**

The Transportation Safety Act of 1974 defines several classes of hazardous materials including explosives, radioactive substances, flammable/combustible liquids and solids, oxidizing or corrosive materials, compressed gasses, poisons, etiological agents (hazardous biological materials), irritating materials and other regulated materials. Under the Resource Conservation and Recovery Act of 1976, the Environmental Protection Agency (EPA) classifies hazardous materials as ignitable, corrosive, reactive, or toxic.

### **Hazardous Chemicals**

Materials characterized as chemicals may be in the form of solid, liquid, granules, powder, vapour or gas. Chemicals commonly used in the construction industry include acids, bases, solvents and alkaline materials (e.g. cement). Hazardous chemicals are listed by a variety of agencies. For instance, NIOSH has compiled a list of some 5000 chemicals that have an inherent hazard (6).

### **Ways of Entry to Human Body**

Chemicals can enter the human body in four ways:

- . **Inhalation:** breathing of gases, vapour, fumes, and dust which can effect lungs, nose, throat, and blood;
- . **Absorption:** chemicals penetrating human skin directly or through cuts;
- . **Ingestion:** chemicals entering through the mouth; or
- . **Injection:** chemicals entering the body purposely or accidentally.

Besides these four routes of entry, some materials may be harmful in direct contact with external tissue. Examples are burns, dermatitis and eye irritation problems resulting from the skin or eye making contact with harmful substances.

### **Health Effects of Exposure**

It is important to note that the likelihood and severity of the health effects from harmful substances depend on the type and quantity of the substance, the rate and duration of exposure, and what happens to the substance in the body. Most hazardous substances affect particular organs of the body; some affect the nervous system, or blood. Exposures can be acute or chronic. An example of an acute effect is a strong acid or caustic contacting a tissue and destroying it. Chronic effects of hazardous materials are observable after a latency period, which is usually the case with carcinogens. Chemical exposure may

affect different people differently, an example being the case of an allergic reaction.

### **Classification Based on Health Effects**

It is also possible to classify hazardous materials based on their health effects. **Asphyxiants** are materials which cause oxygen displacement in a breathing atmosphere and interfere with oxygen transport and breathing. **Carcinogens** produce cancer, or tumor induction, in man and animals. **Mutagens** cause changes in the genetic structure in a current generation of animals or humans, whose effects can show up in future generations in the form of cancer or some mutation. **Teratogens** are substances that cause malformations or serious abnormalities in a human or animal fetus. Finally, lung disorders such as **asbestosis** or **silicosis** can result from inhalation of fibrous or fine particulate materials.

### **Federal Laws on Control of Hazardous Materials**

There are a number of federal laws governing the control of hazardous materials for public safety and health. The Toxic Substances Control Act (TSCA) of 1976 requires all new chemicals to be tested for safety. The Resource Conservation and Recovery Act (RCRA) of 1976 regulates the generation, treatment, storage and disposal of hazardous wastes, and has instituted a manifest system for tracking hazardous materials from creation to disposal or use. The Hazardous Materials Transportation Act of 1974 controls the packaging, labelling and transportation of hazardous materials. The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980 and Superfund Amendments and Reauthorization Act (SARA) of 1986 deal with hazardous waste site cleanup.

### **Right-to-Know Laws**

Federal and state right-to-know laws came about as a result of increasing public demand for open information regarding the dangers of chemicals. To comply with the Emergency Planning and Community Right-to-Know Act of 1986 (also called SARA Title III) employers must inform their employees inside and citizens outside a plant about the dangers of chemicals at the site. This act covers the labelling and storage requirements, and mandates the use of material safety data sheets (MSDS) to provide details on the chemicals or compounds and list the procedures for protection from related hazards. The OSHA format for MSDS is presented in Figure V-1.

### **Hazard Communication Standard**

The OSHA Hazard Communication Standard (29 CFR 1926.59) requires employers to inform their employees of the hazards associated with the use of and exposure to chemicals in the workplace. Originally applicable to manufacturing, this standard was extended to the construction industry effective May 23, 1988. Any chemical known to be present in the workplace, in such a manner that employees may be exposed to it under normal conditions of use or in a foreseeable emergency, is covered under this standard. To comply with this standard, the employer must:

**Material Safety Data Sheet**  
May be used to comply with  
OSHA's Hazard Communication Standard,  
29 CFR 1910.1200. Standard must be  
consulted for specific requirements.

**IDENTITY** (As Used on Label and List)

**Section I**

Manufacturer's Name

Address (Number, Street, City, State, and ZIP Code)

**U.S. Department of Labor**  
Occupational Safety and Health Administration  
(Non-Mandatory Form)  
Form Approved  
OMB No. 1218-0072



*Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.*

Emergency Telephone Number

Telephone Number for Information

Date Prepared

Signature of Preparer (optional)

**Section II — Hazardous Ingredients/Identity Information**

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (optional)
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**Section III — Physical/Chemical Characteristics**

Boiling Point

Vapor Pressure (mm Hg.)

Vapor Density (AIR = 1)

Solubility in Water

Appearance and Odor

Specific Gravity (H<sub>2</sub>O = 1)

Melting Point

Evaporation Rate  
(Butyl Acetate = 1)

**Section IV — Fire and Explosion Hazard Data**

Flash Point (Method Used)

Extinguishing Media

Special Fire Fighting Procedures

Unusual Fire and Explosion Hazards

Flammable Limits

LEL

UEL

**Figure V-1. OSHA format for material safety data sheets**

## Section V — Reactivity Data

Stability	Unstable	Conditions to Avoid
	Stable	

Incompatibility (Materials to Avoid)

Hazardous Decomposition or Byproducts

Hazardous Polymerization	May Occur	Conditions to Avoid
	Will Not Occur	

## Section VI — Health Hazard Data

Route(s) of Entry:                      Inhalation?                      Skin?                      Ingestion?

Health Hazards (Acute and Chronic)

Carcinogenicity                      NTP?                      IARC Monographs?                      OSHA Regulated?

Signs and Symptoms of Exposure

Medical Conditions  
Generally Aggravated by Exposure

Emergency and First Aid Procedures

## Section VII — Precautions for Safe Handling and Use

Steps to Be Taken in Case Material is Released or Spilled

Waste Disposal Method

Precautions to Be Taken in Handling and Storing

Other Precautions

## Section VIII — Control Measures

Respiratory Protection (Specify Type)

Ventilation	Local Exhaust	Special
	Mechanical (General)	
		Other

Protective Gloves                      Eye Protection

Other Protective Clothing or Equipment

Work/Handling Practices

Figure V-1. (Continued)

## **Employer's Duties**

- . Conduct an inventory and list all hazardous chemicals on the job-site, and maintain an up-to-date inventory;
- . Collect and maintain the appropriate MSDS's;
- . Develop a written Hazard Communication Program (must be maintained at the job-site);
- . Ensure that containers for all chemicals are properly labelled; and
- . Establish a continuing training and information program for employees exposed to hazardous chemicals;
- . The training program must include methods for hazard identification; physical and health hazards of chemicals on the jobsite; protective measures to be taken in case of exposure; specific safe work practices, emergency release or spill equipment; and the details of the Hazard Communication Standard such as labels and warning systems, and MSDS.

## **Material Handling Hazards**

Improper handling of materials can lead to several hazards. Some relate to poor housekeeping; some are unique to particular activities, equipment or materials. Hazards may stem from a lack of proper planning of the material handling jobs such as delivery, storage and movement, or from failure to properly communicate with and provide clear instructions to participating employees. Loading and unloading operations associated with material delivery can create hazards resulting from failed lifting equipment (e.g. buckling of crane boom, collapse of a conveyor support, rigging failure, breaking of a wire or chain rope), which can cause serious injury to workers. Manual lifting and material handling also commonly cause injuries and health problems like strain and sprain of muscles, torn ligaments and spinal disc injury and hernia. Improperly stacked or stored materials may cause items to fall down on people or tip over from piles, overload the storage shelf or area, or protrude into traffic ways and aisles, creating obstacles or tripping hazards. Improper segregation of materials may create additional hazards from fire, explosion and corrosion. Loads in motion also pose safety hazards if not properly controlled. Moving loads may strike other objects or persons causing property damage and bodily injury. Ropes, chains and slings are rigging devices used to lift loads. The main hazards of rigging are failures due overloading, deterioration or wear, harmful and improper rigging.

## **Material Handling Controls**

Effective control of material handling hazards starts with good planning of the site layout and activities, and continues with proper storage and housekeeping practices. Training in hazard communication requirements, safe manual lifting and handling procedures, and safe operation of material handling equipment are also essential.

## **Worksite Layout**

The need to move materials safely and efficiently should be included in planning for the arrangement or modification of work places. Detail should address concerns such as flow of materials, methods of site transport, purchase of safe operating equipment, ergonomic factors,

loading and unloading facilities, minimization of manual handling tasks, adequate availability and arrangement of storage areas, choice of hazardous material locations, and future maintenance requirements.

## **Storage**

Planned material storage lessens the handling needed to move materials for processing, use, or shipment. Movement of materials is facilitated by providing adequate storage space at receiving, processing, and shipping areas. Storage should be organized to reduce hazards and to enable safe and practical placement and removal of materials. Storage equipment, (racks, bins, pallets, etc.) should match the temporary or long term needs. Bags, bundles, and other containers need to be suitably tacked, blocked, interlocked, and limited in height. For open pits, tanks, vats, etc., covers and guardrails must be provided to reduce contact and fall hazards. Special precautions are required for storage of hazardous materials with consideration given to the level of protection needed for each hazardous material. Attention should be focused on items that by their nature are recognized to be harmful, e.g., those which are explosive, flammable, toxic, asphyxiating, or biologically contaminated.

### *Storage According to Use, Kind and Size*

Basically, all materials should be stored according to their use and characteristics. Materials should be segregated according to kind and size, and should be placed in easily accessible, neat, and orderly piles. Specific storage methods include cross stripping for lumber, piling for sacked materials such as cement, stepping, cross piling, and cross tying. Materials stored on constructed floors, or supporting members should not be in excess of the strength of these members. Materials should not be stored on scaffolding or other temporary structures beyond immediate need.

## **Control of Explosive Materials**

The following precautions should be considered for prevention of mishaps associated with explosive materials:

- . Smoking, flames, intoxicants, and any item that can cause a spark around explosives should be forbidden.
- . Transportation vehicles should be equipped with fire extinguisher and aluminum deck surfaces. Vehicle battery and wiring should not come in contact with explosives. Proper warning signs such as "EXPLOSIVE", "DANGER", and red flags should be displayed on the vehicle.
- . Vehicles should not be overloaded and the cargo should be secured. Explosives should be received and stored for daily use only. They should be stored in fire and bullet resistant buildings, protected from weather and fire. They should be accessible only to authorized personnel.
- . Metal tools should not be used for handling explosives.
- . All explosives should be handled by well trained personnel, according to manufacturer's instructions, with one supervisor in charge of the entire explosive operations.

### **Control of Flammable Materials**

Many of the safety recommendations for explosive materials are also applicable to flammable liquids. Specifically:

- . Flammable gases and liquids should be segregated from all other materials, equipment and activities which may create sparks or flame.
- . Flammable liquids should not be stored adjacent to gases. They should be stored in fire resistant structures with approved fire extinguisher, mortars, electric switches and ventilators.
- . Flammable liquids should be stored at a minimum amount in approved containers, and should be labelled for identification.
- . All containers and dispensing equipment should be approved for the specific use, and should be of the non-sparking type (especially during transfer of the flammables from containers).
- . Corrosive materials should be bonded, vented and equipped with spill prevention catchments.
- . Containers previously used for other flammable liquids should not be reused for different liquids unless the container is thoroughly purged.
- . All personnel handling flammable liquids should be trained in hazard recognition and prevention.
- . Unidentifiable flammable liquids should not be used until the nature of their contents is confirmed.

### **Housekeeping**

The AGC Safety Manual (1) lists the following recommendations for good housekeeping:

- . In storage areas materials should be maintained in neat stockpiles for ease of access. Keep aisles and walkways clear of loose materials and tools.
- . Clean up loose materials, waste, etc. in work areas immediately. This is especially important in aisles and in the vicinity of ladders, ramps, stairs, and machinery. Tools and loose materials should be removed immediately if a hazard is created.
- . In areas used by personnel, empty bottles, containers, and papers should not be allowed to accumulate where lunches are eaten on the job site. Trash disposal cans should be provided.
- . Spills of oil, grease, or other liquid should be removed immediately or sprinkled with sand.
- . An effective means of managing solid waste is the provision of suitable receptacles for waste and scrap. Combustible waste, such as oily rags, paper, etc., should be stored in an appropriate covered container, and disposed of regularly.
- . Protruding nails should either be removed or bent over. Cleaned lumber should be stacked in orderly piles. Workers performing this task should wear heavy gloves and footwear with puncture-resistant soles.
- . Adequate lighting should be provided in or around all work areas, passageways, stairs, ladders, and other areas used by workers.

### **Proper Manual Lifting**

Manual lifting remains an important part of the construction process and should be performed by workers who are trained in the proper method of lifting. According to Potts (8), the objectives of lifting training are:

*Objectives of  
Lifting Training*

- . To inform workers of the consequences of improper lifting;
- . To teach how to avoid unnecessary stress in lifting; and
- . To have workers become aware of their personal physical limits.

**Back Injuries**

Instruction in the basic facts of manual handling should concentrate on how back injuries occur, the frequency of injuries, the long term effects, and the keys to injury avoidance. Employees also need to learn the general and specific rules for safe lifting techniques. The general rules call for the right attitude toward lifting (i.e. "think before you lift!") and practice of self-discipline. The specific rules are more descriptive on how to lift properly. The seven general rules for safe lifting are:

**General Rules  
for Safe Lifting**

- 1) **Lift comfortably.** Although presently there are different views on the position to lift correctly, the new concept is to lift with or without a straight back depending upon what is most comfortable to the individual. The traditional view is to lift with a straight back and bent knees.
- 2) **Avoid unnecessary bending.** Whenever possible place objects on waist level surfaces and not on the floor.
- 3) **Avoid unnecessary twisting.** Turn your feet, not your hips or shoulders.
- 4) **Avoid reaching out.** Hold heavy objects close to your body. Avoid reaching out to pick up an object.
- 5) **Avoid excessive weights.** Get help or use a mechanical device rather than lifting a load that is too heavy.
- 6) **Lift gradually.** Lift slowly, smoothly and without a jerking motion.
- 7) **Keep in good physical shape.** Get proper exercise and maintain a proper diet.

**Specific Rules  
for Safe Lifting**

The traditional and more specific technique for lifting is the two-hand squat lift method. This lifting method, according to the National Safety Council (9), consists of six basic steps.

- 1) **Correct feet positioning.** Straddle the load with one foot beside the load and one foot behind the object.
- 2) **Keep the back straight and knees bent.**
- 3) **Get a good grip.** Use a full-palm grip not just the fingertips.
- 4) **Pull the load as close to the body as possible.** Place elbows and arms close to the body.
- 5) **Tuck the chin in.**
- 6) **Keep the body positioned over the feet.** Start the lift with the rear foot.

**NIOSH Equation  
for Manual  
Lifting**

A rational approach to safe manual lifting is establishing weight limits for individuals. NIOSH (10) has developed an equation for this purpose based upon biomechanical, physiological and psychophysical factors and criteria. This equation is expressed as:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$$

where:

## Recommended Weight Limit

RWL= Recommended weight limit; and

	<i>Metric</i>	<i>US customary</i>
LC = load constant	= 23 kg	51 lbs
HM = horizontal multiplier	= (25/H)	(10/H)
VM = vertical multiplier	= (1-(0.003 V-75 ))	(1-(0.0075 V-30 ))
DM = distance multiplier	= (0.82+(4.5/D))	(0.82+(1.8/D))
AM = asymmetric multiplier	= (1-(0.0032A))	(1-(0.0032A))
FM = frequency multiplier	(from Table V-2)	
CM = coupling multiplier	(from Table V-3)	

In the above formulas:

- H = horizontal distance of hands from midpoint between the ankles. Measure at the origin and the destination of the lift (cm or in).  
V = vertical distance of the hands from the floor. Measure at the origin and destination of the lift (cm or in).  
D = vertical travel distance between the origin and the destination of the lift (cm or in).  
A = angle of asymmetry-angular displacement of the load from the sagittal plane. Measure at the origin and destination of the lift (degrees).  
F = average frequency rate of lifting measured in lifts/min. Duration is defined to be:  $\leq 1\text{h}$ ;  $\leq 2\text{h}$ ; or  $\leq 8\text{h}$  assuming appropriate recovery allowances (see Table V-3).

## Lifting Index

Based on this equation, a lifting index (LI) has been defined as the ratio of the load lifted to the recommended weight limit. The concept suggests that the risk of injury increases as the load or job demands exceeds some baseline capacity of the worker. LI is an index of relative physical stress, and can be used to identify hazardous lifting tasks.

## Manual Handling Assist Devices

A variety of tools and equipment are available to assist in the manual handling of materials. Use of such items will aid in reducing strains and other injuries. Each should be used only for the designed task, inspected before use, and kept in good condition. Some of the tools/equipment safeguards are (17):

### Hooks

Hooks should be used in a manner so as not to glance off hard objects. They should be stored in a safe place and maintained in ready-to-use condition.

### Bars

In working with bars, the body should be positioned to avoid contact due to slippage or fall of material.

### Two-wheel Trucks

Trucks with widely-spaced wheels are recommended to prevent overloading and knuckle guards should be furnished to protect hands from contacts. Hand trucks should be in a vertical position when not in use.

**Table V-2**  
**Coupling multiplier - CM (10)**

Coupling	Coupling multipliers	
	V<75 cm (30 in)	V≥75 cm (30 in)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

**Table V-3**  
**Frequency multiplier - FM (10)**

Frequency lifts/min	Work duration					
	≤ 1h		≤ 2h		≤ 8h	
	V<75	V≥75	V<75	V≥75	V<75	V≥75
0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.52	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

**Note:** Values of V are in cm; 75 cm = 30 in.

### *Dollies*

Materials should be loaded evenly on dollies to prevent tipping and obstruction of view. They should be pushed rather than pulled, unless specially designed to be pulled.

### *Rollers*

Hands and feet should be kept away from pinch points and the rollers should be extended beyond the load.

### *Jacks*

Properly rated jacks should be used for the load, placing the jack on level, stable, and clean surface. Metal-to-metal contact should be avoided by using wooden shims. The load should be blocked after the jacklift.

### **Rigging Safety**

Rigging of loads must be done with relative precision and performed by trained, experienced personnel. Competent supervision is needed to see that (a) suitable rigging equipment is available having the necessary capacity for the job, (b) rigging equipment is in safe working condition, (c) loads are rigged properly, and (d) the safety of the rigging crew and other affected personnel is maintained. The following safety precautions and procedures are recommended in regard to safe rigging (12):

- . Learn the safe working load of the equipment, tackle, and hardware before use.
- . Determine the weight of the load prior to rigging it.
- . Use the proper rigging equipment for the job to be performed.
- . Examine all hardware, equipment, tackle, and slings before use and destroy defective components. Inspect daily for wear and abrasion, broken wires, worn or cracked fittings, loose seizings and splices, kinking, crushing, flattening, and corrosion.
- . Never exceed safe working loads of equipment, tackle and hardware.
- . Allow for a greater degree of safe working limits, when conducting other than center of gravity lifts.

### **APPLICABLE OSHA STANDARDS**

Representative OSHA standards applicable to Material Handling as covered in this part of the module are given in Table V-4.

**Table V-4  
OSHA Standards Related to Material Handling**

#### **29 CFR 1926 Subpart C - General Safety and Health Provisions**

<u>Section</u>	<u>Topic</u>
1926.20	General safety and health provisions
1926.24	Fire protection and prevention
1926.25	Housekeeping
1926.26	Illumination
1926.27	Sanitation
1926.28	Personal protective equipment

#### **29 CFR 1926 Subpart D - Occupational Health and Environmental Controls**

<u>Section</u>	<u>Topic</u>
1926.50	Medical services and first aid
1926.51	Sanitation

#### **29 CFR 1926 Subpart F - Fire Protection and Prevention**

<u>Section</u>	<u>Topic</u>
1926.150	Fire protection
1926.151	Fire prevention
1926.152	Flammable and combustible liquids
1926.153	Liquefied petroleum gas (LP-Gas)
1926.154	Temporary heating devices

#### **29 CFR 1926 Subpart G - Signs, Signals, and Barricades**

<u>Section</u>	<u>Topic</u>
1926.200	Accident prevention signs and tags
1926.201	Signalling
1926.202	Barricades

**Table V-4 (Continued)**

**29 CFR 1910 Subpart G - Occupational Health and Environmental Control**

<u>Section</u>	<u>Topic</u>
1910.94	Ventilation
1910.96	Ionizing radiation
1910.97	Nonionizing radiation

**29 CFR 1910 Subpart H - Hazardous Materials**

<u>Section</u>	<u>Topic</u>
1910.101	Compressed gases (general requirements)
1910.102	Acetylene
1910.103	Hydrogen
1910.104	Oxygen
1910.105	Nitrous oxide
1910.106	Flammable and combustible liquids
1910.107	Spray finishing using flammable and combustible materials
1910.109	Explosives and blasting agents
1910.110	Storage and handling of anhydrous ammonia

**29 CFR 1910 Subpart I - Personal Protective Equipment**

<u>Section</u>	<u>Topic</u>
1910.132	General requirements
1910.133	Eye and face protection
1910.134	Respiratory protection
1910.135	Occupational head protection
1910.136	Occupational foot protection
1910.137	Electrical protective devices

**29 CFR 1910 Subpart J - General Environmental Controls**

<u>Section</u>	<u>Topic</u>
1910.141	Sanitation
1910.144	Safety color code for marking physical hazards
1910.145	Specifications for accident prevention signs and tags

**29 CFR 1910 Subpart N - Materials Handling and Storage**

<u>Section</u>	<u>Topic</u>
1910.176	Handling materials - general
1910.177	Servicing multi-piece and single piece rim wheels
1910.178	Powered industrial trucks
1910.180	Crawler, locomotive, and truck cranes
1910.181	Derricks
1910.182	Effective dates
1910.183	Helicopters
1910.184	Slings

**29 CFR 1910 Subpart Z - Toxic and Hazardous Substances**

<u>Section</u>	<u>Topic</u>
1910.1000	Air contaminants
1910.1001	Asbestos, tremolite, anthophyllite, and actinolite
1910.1002	Coal tar pitch volatiles, interpretation of term
1910.1003	4-Nitrobiphenyl
1910.1004	alpha - Naphthylamine
1910.1006	Methyl chloromethyl ether
1910.1007	3,3 - Dichlorobenzidine (and its salts)
1910.1008	bis - Chloromethyl ether
1910.1009	beta - Naphthylamine
1910.1010	Benzidine
1910.1011	4 - Aminodiphenyl
1910.1012	Ethyleneimine
1910.1013	beta - Propiolactone
1910.1014	2 - Acetylaminofluorene
1910.1015	4 - Dimethylaminoazobenzene
1910.1016	N - Nitrosodimethylamine
1910.1017	Vinyl chloride
1910.1018	Inorganic arsenic
1910.1025	Lead
1910.1027	Cadmium
1910.1028	Benzene
1910.1029	Coke oven emissions
1910.1030	Bloodborne pathogens
1910.1043	Cotton dust
1910.1044	1,2-dibromo-3-chloropropane
1910.1045	Acrylonitrile
1910.1047	Ethylene oxide
1910.1048	Formaldehyde
1910.1050	Methylenedianiline
1910.1101	Asbestos
1910.1200	Hazard communication

## **WELDING AND CUTTING**

Welding is defined as the union of metal; and cutting is defined as severing or removing of metal. Both tasks are accomplished by heating metals at suitable temperatures. Welding and cutting are generally achieved by three methods:

- 1) **Gas welding and cutting**, which involves the use of oxygen, acetylene and other gaseous fuels to generate heat;
- 2) **Arc welding and cutting**, which uses electric arc to create heat; and
- 3) **Resistance welding**, which involves the generation of heat by resistance to flow of electric currents.

### **Welding and Cutting Hazards**

Welding and cutting produces a number of hazards to operators, which are described below:

#### *Inhalation*

Fumes can cause intoxication through inhalation especially when toxic materials such as lead, zinc, and cadmium coated materials are welded. This hazard is more critical in confined spaces.

#### *Burning*

Unprotected skin can be burned if it comes in contact with molten metal and sparks.

#### *Fire*

Cutting and welding are major producers of fire on construction sites. Fires can be created by flying sparks or molten metal. Some flammable materials may ignite in the presence of pure oxygen. Fires can also be created by welding near combustible materials or containers which contain (or have previously contained) combustible material.

#### *Explosion*

Explosions can be created by welding around containers of explosives. Explosion hazards are more critical during gas welding. Hazards are also associated with improper storage and handling of gas cylinders (such as exposure to heat or cold impact, etc.). Oxygen also forms a highly explosive mixture with acetylene and other gaseous fuels.

#### *Electrical Hazards*

In the case of arc welding and cutting, electric shock is a major hazard, and can be fatal. High voltage electric shock, from faulty wiring and grounding, or exposure to water, are the typical sources of electrical hazards. Ultraviolet rays caused by electric arcs can damage the eye lens by "sunburning" its surface. Ultraviolet light can also produce burns and tumors on the skin which may turn malignant. Ultraviolet light produces ozone and can form highly toxic substances in reaction with other chemicals.

#### *Other Common Hazards*

Other common hazards associated with welding and cutting include the following:

- . Chipping of excess metal or faulty welding can injure the eye.
- . Working with goggles and face shields can reduce visibility resulting in accidents.
- . Handling hot equipment may cause burns.
- . Extreme noise levels may be harmful to hearing.

. Radiation exposure may have latent adverse health effects.

**Control of  
Fire Hazards**

Suitable fire control devices should be ready for emergency use near welding operations. OSHA standards require that objects that present fire hazards should be removed if practical; otherwise they should be securely covered. Containers previously used to store flammable substances must be either filled with water, or thoroughly cleaned, before welding, cutting or heating.

***Fire Watcher***

Flying sparks and molten metal can travel up to 25 to 30 feet and retain sufficient heat to ignite combustible material. Therefore, a second person should serve as a "fire watcher" during welding and cutting and continue this task for 30 minutes after the operation has ceased.

**Welding  
Equipment  
Safety**

All electrical welding equipment should conform to the requirements of the National Electric Manufacturers Association or the Underwriters Laboratories (1). Power circuits should conform to the requirements of the National Electric Code. Electric holders should have adequate current capacity and insulation against shock, shorting or flashing. Electric stubs should be disposed of in a fire-proof container.

**Protective  
Clothing and  
Equipment**

Protective clothing should cover all parts of the body, depending on the nature of the work. It must include flame resistant clothing free of oil and grease. Safety goggles or face shields with tinted lenses (to protect against chipping hazards, sparks and harmful rays), flame resistant gauntlet gloves, aprons, safety shoes, leggings, and respirators must be used during welding and cutting.

**Ventilation**

OSHA standards require the use of mechanical ventilation to remove metal fumes in excess of established limits. Freely moveable exhaust hoods should be placed near the source of the fumes. The use of oxygen for ventilation purposes is prohibited by OSHA. Ventilation of confined spaces is also an important consideration during welding or cutting operations. In such cases workers can be protected by using airline respirators, and should maintain communication with a person outside the confined space (see the Confined Space Entry section).

**Housekeeping**

As previously emphasized, proper housekeeping can eliminate many hazards associated with fire, explosions and electrical shocks. Removal of loose combustible materials such as wood shavings, saw dust, materials soaked in flammable liquids, highly volatile materials such as fuels and solvents are important to fire safety. Wood and other combustible material should be shielded from sparks. Electrical wires for welding equipment should be regularly inspected for safe operation.

**APPLICABLE  
OSHA STANDARDS**

The OSHA standards applicable to welding and cutting as covered in CFR 1926 Subpart J are provided in Table V-5.

**Table V-5**  
**29 CFR 1926 Subpart J - Welding and Cutting**

<u>Section</u>	<u>Topic</u>
1926.350	Gas welding and cutting
1926.351	Arc welding and cutting
1926.352	Fire prevention
1926.353	Ventilation and protection in welding, cutting, and heating
1926.354	Welding, cutting and heating in way of preservative coatings

## **CONCRETE CONSTRUCTION**

Concrete is a mixture of portland cement, aggregate and water. Portland cement is a hydraulic material which forms a paste when it chemically reacts with water. This paste binds the aggregate into a hardened mass. Concrete has a wide variety of applications in the construction industry. It can be formed to many shapes. Its resistance to fire and moisture, and its durability are desirable for many components of a structure. Cast-in-place concrete can be prepared on the jobsite, or can be delivered in ready-mixed form utilizing special trucks. This is a labor-intensive method of construction. It involves the erection of formwork and shoring; delivery and placement of the reinforcing steel; mixing, handling, and placing of the fresh concrete; surface preparation and finishing; curing; and removal of the formwork. Precast concrete members are also manufactured to specific shapes at a plant and delivered to the project sites.

### **Concrete Hazards**

Interaction between the workers and the concrete material can lead to a variety of safety and health hazards. Hazards associated with concrete construction can be categorized as:

- . Material hazards;
- . Hazards of construction operations and jobsite conditions; and
- . Structural failures.

### **Material Hazards**

Some materials used in concrete construction may pose certain safety and health hazards if they are not properly handled. These hazards are discussed in the following paragraphs.

#### ***Cement***

Dry cement is abrasive and can cause cuts or scratches on skin. Wet cement is an alkali and can cause first, second and third-degree skin burns, which can lead to permanent disfigurement.

#### ***Silica***

Grinding, sand blasting, dry cutting and surface cleaning are major producers of cement dust. Sand blasting generates fine dust particles

which contain high concentrations of silica. Prolonged inhalation of silica that exceeds permissible exposure limits can lead to lung diseases such as silicosis.

#### *Form Oil*

Form oil and form release agents are sprayed on the forms immediately prior to the placement of concrete to prevent adhesion of wet concrete to wooden forms. A low pressure spray known as "Hudson Spray" is commonly used for this application and it creates fumes that can be toxic and hazardous, especially in confined spaces. Most form oils are low hazard petroleum fuels; however, long-term inhalation may lead to respiratory irritations. Some form release agents also contain solvents which increase potential health hazards. High concentrations of isopropyl alcohol, or xylene can cause loss of coordination and eye irritation. Skin or eye contact with these agents are the primary cause of health problems. Repeated absorption can cause various types of skin irritation and damage.

#### *Acids*

Various acidic solutions used for removing stains from concrete surfaces can also pose health hazards. They are generally mixed on the job site and brushed on the concrete. Contact with skin and eye can cause burns, and the inhalation of fumes can damage respiratory organs. The severity of these problems varies according to the type of substance, concentration, and duration of contact.

#### *Other Hazardous Substances*

There are a variety of other substances used in concrete construction which may be potentially hazardous. These include the many types of curing compounds which are applied on the freshly poured material to promote quick setting and prevent surface cracking. Bond breakers are applied in between existing and newly poured surfaces to prevent adhesion. Several sealants and waterproofing agents are also used in concrete. Many of these substances may possess inhalation and contact hazards.

#### **Formwork and Shoring Hazards**

Formwork is the system which supports freshly poured concrete as it cures. It also supports the workers (as they perform work), materials and equipment during construction. Erecting and removing formwork involve a number of operations that can create hazardous conditions, and cause accidents and injuries. The major types of formwork hazards are discussed below.

#### **Falls**

Falls from elevations is a major cause of accidents in concrete construction (13). Erection of formwork is often performed at high altitudes and in difficult positions. Falls from elevations can be caused by lack of proper access and egress to the work area, or lack of adequate fall protection measures such as safety nets, safety belts, and guard rails. Use of the formwork and reinforcing for climbing is a dangerous practice; it can lead to falls.

### **Striking or Falling Objects**

Being struck by falling objects is also a significant cause of accidents in concrete construction, since material handling is a major part of formwork erection. If any material or tool is not completely secured during movement to position, or during use, it can come loose and fall down. Falling objects during formwork stripping operations can also cause safety hazards.

### **Formwork and Shoring Failures**

Safe formwork and shoring is key to safe concrete construction. Failure of formwork or shoring as a temporary structure can have devastating consequences. Deformation of formwork during the curing period jeopardizes the appearance, and more critically the structural integrity of the concrete structure. Inadequate formwork and shoring operations can generate hazards which may ultimately lead to total collapse. Common formwork and shoring hazards are:

### **Common Hazards**

- . Selection of unsuitable formwork and shoring system, and materials for the intended use;
- . Inadequate structural design in terms of capacity of the material, connections, layout details and bracing;
- . Faulty workmanship or design; absence of proper formwork drawings;
- . Soil subsidence due to overload (may become more critical with wet weather);
- . Premature removal of formwork before concrete has obtained its design strength;
- . Improper placement of equipment and construction loads on incomplete or inadequate shoring; and
- . Improper pouring of concrete that causes eccentric loading beyond the formwork's capacity.

Other formwork hazards to workers are improper lifting, slipping and falling, nail and wire puncture, and unsafe use of power and manual tools.

### **Hazards of Reinforcing Steel**

Reinforcing steel is generally delivered to the job site by the fabricator. Once delivered, reinforcing must be unloaded, stored and finally placed in its permanent location. These phases include a great deal of manual handling and mechanical hoisting.

### **Handling Hazards**

Many accidents that occur during concrete construction are due to handling of reinforcing steel (14). Lack of adequate planning creates the first basic hazard. Unplanned delivery and lack of proper communication can result in unloading with inadequate hoisting equipment, inadequate safety equipment and manpower, or possibly receiving the wrong amount or type of reinforcing steel (rebars). These can lead to confusion and hasty decisions jeopardizing safety. Unsafe practices in reinforcement handling also include exceeding the capacity of hoisting equipment and improper lifting (such as lifting from bundle ties). Other common hazards associated with the handling of

reinforcement include:

- . Slips and falls on loose bars;
- . Working at heights;
- . Falling objects;
- . Improper posture while tying steel bars;
- . Working in areas with obstacles such as bar supports and protruding elements;
- . Puncture or injury from exposed reinforcing; and
- . Collapse of reinforcing sections due to insufficient lateral bracing.

### **Structural Failures**

Finally, steel reinforcement is the main source of tensile strength in concrete. Placement of the reinforcement generally follows structural and shop drawings. Any design errors, or deviations from contract documents could lead to serious structural problems and failures.

### **Concrete Placement Hazards**

Concrete placement activities involve delivery, transportation, placement, finishing and curing of concrete. These activities can expose the workers to many hazards if the management does not plan for their proper implementation.

#### *Delivery*

The delivery of concrete to the project site starts by scheduling truck arrivals. Failure to preplan the delivery or to position trucks in proper locations may result in unsafe conditions for handling the concrete. Failure to inspect the concrete for conformance to design specifications may result in the use of substandard concrete leading to potential structural failure.

#### *Placement*

Concrete may be deposited into formwork by a variety of methods. In cases where ready-mix trucks are utilized, direct deposit or chute extension can be employed. In other cases, concrete can be transported in wheelbarrows. Conveyers may be used as a means to speed the placement of concrete. Large projects and high-rise structures may require a crane. Mechanical, hydraulic, pneumatic and squeeze operated pumps are utilized to transport concrete over great distances, which can increase productivity. Such methods are particularly economical for massive foundations and large slabs. Typical hazards associated with concrete placement are:

- . Injury and strain caused by handling chutes, shovelling and raking;
- . Overexertion from wheelbarrows;
- . Collapse of poorly constructed conveyer belts, or injury from moving parts;
- . General crane hazards (see later section);
- . Injury caused by separation or surge of high pressure pumps;
- . Improperly maintained hoses with unsecured joints and coupling in the pipeline;
- . Poor communication between the signalmen and operators; and
- . Poor housekeeping.

## **Control of Concrete Hazards**

Controls and precautions against the hazardous substances and hazardous material handling activities are essentially as covered previously in the Material Handling parts of this module. Some specific information will additionally be provided herein.

## **Cement Handling**

In handling cement, workers should wear goggles and close-fitting clothing with gloves snug wrist, ankle, and neck bands. The use of protective cream, and frequent washing are recommended for avoiding skin irritations. Workers handling bulk cement should use both goggles and respirators.

## **Mixers**

All gears, chains, and rollers of concrete mixers should be properly guarded. Waste materials should not be allowed to accumulate around mixers. Ropes and sheaves should be inspected daily. Switches should be locked in open position and tagged; fuses should be removed, and the throttles should be closed when mixers are not operating. Power switchers of mixers should be locked and be left in the off position when workers are cleaning inside the drum.

## **Buckets**

Concrete buckets positioned by crane or overhead cableway should be suspended from deep-throated hooks equipped with a swivel and safety latch. Care should be exercised by the crane operator in swinging the bucket, and a signal person should be engaged for safe operation.

## **Buggies**

Buggies should be kept clean without any material accumulating inside. Handles of buggies should have knuckle guards and should not extend beyond wheels on either side. If ready-mix trucks are unloading into buggies, they should be routed to provide a smooth flow of traffic. If possible, buggies should be routed in a continuous loop to minimize the danger of collision. If a single runway is used, turnouts should be provided. Runways should be smooth running surfaces of sufficient width and strength to support the buggies. Stop cleats should be used when dumping materials.

## **Formwork and Shoring Safety**

Safety of formwork involves adequate structural design and construction, plus safe working conditions for the workers. The working drawings for formwork should give the carpenter in the field a clear picture of what is required and how to achieve it. Besides complete formwork details and dimensions, the drawings should clearly indicate (15):

## **Drawings**

- . Types and strengths of materials to be used in the formwork;
- . Construction loads for which the formwork is designed, including permissible concentrated loads if any;
- . Limits on rates of pour and concrete temperatures;
- . Planned pour sequence and schedule;
- . Pouring pocket and cleanout details;
- . Expansion joint details;

- . The complete plan for shoring and reshoring, showing braces and other details; and
- . Maximum shore loadings for the mudsills, and the assumed soil bearing values used in sill design.

Good housekeeping is important in preventing injuries caused by falling objects, nails, splinters, etc. Workers constructing formwork or placing reinforcing steel where there is a falling hazard should wear safety belts or secure other forms of adequate fall protection.

### **Safety Factor for Shoring**

Shoring and shoring equipment should have a safety factor based on approved procedures. According to AGC (1), for normal concrete and reinforcement, the design load (dead plus live) for formwork shoring should not be lower than 100 pounds/square foot (psf) regardless of the slab thickness. However, the minimum allowance for live load and formwork should be at least 20 psf in addition to the weight of concrete. When motorized carts are used, the design loads should be increased by 25 psf. Shoring design should consider all details and special conditions of the structure, including heavy beams, use of cantilevered slabs, and the method of transporting concrete to the placement location. The design must also consider lateral loads such as wind, impact of placement, inclined supports, cable tensions and forces imposed by the movement of equipment.

### **Sills**

Sills are footings (usually wood) which distribute vertical loads to the soil and should be capable of carrying the load without settlement or displacement. Suitable sills should be used on any support system where vertical shoring equipment could concentrate an excessive load on a thin concrete section, or on any floor or support.

### **Inspection**

Continual inspections of formwork and shoring should be performed during concrete pouring operations to make any necessary corrections and adjustments. Before erection, all shoring equipment should be inspected to ensure it is the type specified in the design and is free of defects such as cracks and excessive knots in wooden members. Tubular steel frame shoring should be inspected for excessive rusting, straightness of parts, dents or kinks, damaged welds, and operation of locking devices. After erection, the shoring equipment should be re-inspected prior to placement.

### **Shoring Design Plan**

The shoring design plan should be checked to ensure that:

- . Layout details, including side bracing, have been met;
- . All vertical shoring is plumb. The maximum allowable deviation from the vertical is 1/8 inch in 3 feet;
- . The spacing between towers and the spacing between cross bracing is not greater than that shown on the shoring layout;
- . All bracing devices are secured; and
- . All base plates or adjustment screws firmly contact the footing or sill.

## **Formwork and Shoring Removal**

Formwork and shoring should never be removed too early, allowing concrete to set properly. Only personnel actually engaged in form stripping should be allowed in the area during these operations. Hard hats, gloves, and heavy-soled shoes should be worn. In cutting tie wires under tension, care should be taken to prevent backlash which might hit the body, particularly the face, eyes, or throat. Eye and face protection is recommended. Safe removal depends on:

- . Rate of strength gain in concrete;
- . The accuracy of strength determination of in-situ concrete; and
- . The level of temporary stress and deformation a structure can withstand.

## **Testing of Cylinders**

Tests on job-cured cylinders are used to ensure whether concrete has attained the strength required to carry the load. Job specifications and local building codes also regulate form removal (15).

## **Reinforcing Installation Safety**

The following safety measures are recommended to reduce injuries during rebar handling and installation (16):

- . Use mechanical hoisting equipment to place bundled bars in close proximity to the desired work location. This practice minimizes manual handling and reduces the chance of injury.
- . Use the proper lifting equipment in combination with two-part slings, chokers, cables and guy wires to transport reinforcing bars safely.
- . Space two-part slings properly to balance loads of 20 feet or longer.
- . Tightly secure bundles of rebars with a tag line to prevent striking a worker or structure.
- . Tie bundles of rebar securely to prevent loads from slipping and falling on someone.
- . Never hoist bundles by the wire wrappings that tie the bars together.
- . Use shackles or hooks with a safety latch for hoisting.
- . Never land hoisted bundles, or drop carried bars on formwork without ensuring the formwork is strong enough to support the additional load. This practice can prevent possible collapse and consequent injury.
- . Use jigs, frame tables and other devices to facilitate the assembly of column cages and other prefabricated units and to eliminate constant bending by the worker.
- . Use at least two workers to manually transport bars of excessive length and weight. Ensure the bars are properly tied together.
- . Lift with the arms and legs-not your back.
- . Wear protective gloves, especially during unloading and stockpiling.
- . Wear head protection and eye protection when placing/tying rebars.
- . Never wear loose clothing or jewelry which can become snagged on rebar dowels and formwork.
- . Learn to tie rebar stifflegged instead of in a squatting position. This practice will help prevent many aches and pains.
- . Avoid field cutting and welding reinforcement. However, if necessary, take the proper precautions with regard to hand and power tools,

- prevention of fires and the use of personal protective equipment.
- . Take measures to prevent unrolled wire mesh from recoiling. Such measures include securing the ends or turning over the mesh.
- . Ensure that the twisted ends of tie wire are turned under the rebar to prevent puncture wounds from their sharp ends.
- . Place planking over reinforcing mats to afford footing and prevent tripping or falling injuries.
- . Cover exposed reinforcing rods with wood or other appropriate material to prevent tripping and falling injuries.
- . Use recommended safety belts and lanyards with positive latches or equivalent fall protection equipment when working at elevations over 6 feet.
- . Tie-off safety belts to secure vertical bars and ensure the safety latch is clipped down instead of up.
- . Practice good housekeeping.

### **Cold Weather Precautions**

Extensive concreting is now carried out during periods of cold weather, utilizing proper techniques of mixing and protection. Heaters of various types are used to heat aggregates and other materials and to maintain proper curing temperatures. These heaters should be frequently checked for proper functioning. When construction areas are enclosed with canvas, plastic film, or other materials and heated, proper ventilation and lighting should be provided. Flame resistant material should be used.

### **Protection Against Cold**

During cold weather concreting, it is extremely important that fresh concrete be protected at all times from exposure to freezing temperatures. Thin slabs lose heat rapidly and should be enclosed, if necessary, to protect them from wind and low temperature effects. When heated materials are used in concrete production, it is generally advisable to add the cement to the mix last to prevent flash sets (which harms strength). Concrete should not be allowed to dry out during periods of protective heating. Forms should not be removed until it is certain that the concrete has developed sufficient strength to sustain all live and dead loads which will be imposed. Workers should wear proper clothing to protect themselves from frost-bite, hypothermia, and pneumonia (7).

### **APPLICABLE OSHA STANDARDS**

OSHA's 29 CFR 1926 Subpart Q is the standard which covers both concrete and masonry construction. The full scope of this standard is shown in Table V-6, although aspects related to cast-in concrete are primarily addressed in this module.

**Table V-6  
29 CFR 1926 Subpart Q-Concrete and Masonry Construction**

<u>Section</u>	<u>Topic</u>
1926.700	Scope, application, and definitions applicable to this subpart
1926.701	General requirements
1926.702	Requirements for equipment and tools
1926.703	Requirements for cast-in-place concrete
1926.704	Requirements for precast concrete
1926.705	Requirements for lift-slab operations
1926.706	Requirements for masonry construction

## **STEEL ERECTION**

### **Advance Planning**

Steel erection includes all activities involved in receiving, distribution, positioning and, connecting the structural and non-structural steel components of a building. Depending upon the structural design of a building, these components may include various shapes of columns and beams, girders and trusses, purlines, etc. Steel erection operations can be divided into two segments: advance planning and operations.

Advance planning includes preparation of the shop drawings based on the structural design provided in the contract documents. Shop drawings contain information pertaining to the type and physical dimensions of steel members, connection details, welding information, erection sequence, etc. Approval of shop drawings by the structural engineer of record, fabricating, and shipping the steel to the construction site according to the sequence of erection complete the advance planning phase. Field operations for steel erection include hoisting and positioning the steel, temporary connections, plumbing and permanently bolting or welding the structural members, and decking and attaching the miscellaneous (non-structural) steel members (e.g. ladders).

### **Field Operations**

### **Design Hazards**

Inappropriate design decisions and poor construction practices are the genesis of many hazards experienced during steel erection. Some of the more common problems include:

- . Spatial constraints imposed by design which complicates accessibility and assembly;
- . Complicated and non standard connection details, especially those which must be performed in hazardous conditions such as high altitudes;
- . Tight tolerances and lack of flexibility for adjustment at the time of positioning;
- . Collapse due to instability of the incomplete structural frame (in cases where the structural integrity of members are dependent on interlocking elements or temporary bracing); and
- . Failure due to design errors, or omissions on shop drawings. In many cases these result from poor communications.

### **Erection Hazards**

General hazards associated with welding and cutting, fall protection and scaffolding, rigging and hoisting are covered in the appropriate sections of this module. Some other specific hazards experienced during steel erection include:

- . Conflict with the public right of way;
- . Overhead power lines and activities of other contractors;
- . Fire hazards associated with riveting;
- . Plank failures;
- . Overloading of structural members such as decks or joists from stacking materials;
- . Failure due to improper erection sequence;
- . Failure due to eccentric loading from material storage on structural members; and
- . Faulty workmanship at critical connection points.

## **Design Precautions**

Constructability issues should be addressed in design, including flexibility, sequence of safe erection, non-standard connection details in high altitudes, and sufficient tolerances and landing places to simplify alignment and initial jointing. Extra holes in the structural components should be provided as anchor points for safety harnesses. Bracing and appropriate temporary support for the incomplete structural frame should also be addressed.

## **Shop Drawings**

Good communication between the structural engineer, fabricator and steel erectors can go a long way to eliminate design errors. Proposed design modifications and other concerns should be discussed and approved by the structural engineer. Construction and material loads on incomplete structural frames should be addressed on the shop drawings. The extent of responsibility of each participant in the steel erection operations should be clearly defined in order to prevent errors and omissions. Shop drawings should address and encompass:

- . The sequence of erection, alignment, and connections;
- . Ground level assembly;
- . Slings and lifting, indicating safe lifting positions and maximum weights of the hoisted members;
- . Temporary bracing and support measures to prevent structural failures;
- . Access and safe passages to critical locations;
- . Safety considerations such as guard rails, safety nets, and holes (anchor points) for harnesses;
- . Stacking and storing requirements; and
- . Distinctive marking for similar members to aid in identification.

## **Erection Precautions**

Safety precautions in regard to welding and cutting, fall protection, scaffolding, rigging and hoisting are covered in the appropriate sections of this module. The following recommendations for safety measures in regard to steel erection operations are additionally given here:

- . Establish good management controls and good discipline to assure adherence to the erection plan and to the maintenance of safety features;
- . Monitor the structural performance of erected members by a certified field inspector;
- . Incorporate medical examination for workers with critical responsibilities (e.g. riggers, crane operators, and workers operating at high elevations);
- . Monitor the quality of tools and materials;
- . Ensure that the erection of the vertical elements are in good coordination with the progress of the installation of the permanent floors, and in accordance with the applicable OSHA standards.
- . Provide containers for rivets and bolts to prevent falling objects;
- . Train workers on all aspects of safe erection procedures; and
- . Provide all the necessary personal protective equipment.

**APPLICABLE OSHA  
STANDARDS**

OSHA's steel erection safety standards are covered in 29 CFR 1926 Subpart R, which is presented in Table V-7.

**Table V-7  
29 CFR 1926 Subpart R - Steel Erection**

<u>Section</u>	<u>Topic</u>
1926.750	Flooring requirements
1926.751	Structural steel assembly
1926.752	Bolting, riveting, fitting-up, and plumbing-up

**FALL PREVENTION  
AND PROTECTION**

**Activities Causing  
Fall Hazards**

Falls from elevations, or on a given surface, can occur during a number of construction activities. Fall hazards are also associated with improper storage and/or handling of materials at heights, which result in strike injuries by falling objects. Falls are most likely to occur during the following activities:

- . Using ladders and stairways
- . Working on scaffolding
- . Working near floor openings and other unguarded openings
- . Excavations
- . Working on roofs
- . Steel erection
- . Precast concrete placement
- . Working on elevated and/or suspended platforms
- . Hoisting of materials and workers
- . Material handling and storage.

A substantial number of serious and fatal injuries result from falls. Falls from heights represent one-third of all construction related fatalities and they are the number one cause of deaths on construction sites (17,18).

**Fall Prevention  
vs. Protection**

It is possible to control fall hazards in two ways:

**Fall prevention and fall protection.** Prevention eliminates fall hazards by eliminating the hazardous conditions. Protection, on the other hand, provides fall arrest and safety measures when the hazardous condition can not be eliminated.

**FALL PREVENTION**

An important step in fall prevention is the provision of safe access and egress by the proper use of ladders and scaffolding. Other issues regarding fall prevention include open sides and floor openings, steel erection and roofing activities:

## **Ladder Hazards**

Selection, inspection, maintenance, and proper use of ladders are the key factors in eliminating the related hazards. Selection considerations are duration of work, location, and height. There are two categories of ladders; portable and fixed. Portable ladders should only be used for short durations, moderate heights, or when the ladder needs to be frequently relocated. Portable ladders can be manufactured or job-built. In the latter case, ladders should be constructed to meet the OSHA standards. Ladders should be built from seasoned, straight grained wood, free from knots and defects. Fixed ladders should be used when regular and long term access from one level to another is required.

## **Maintenance and Inspection**

Ladders should be maintained in good condition. They should be regularly inspected for damage and defects such as deterioration, corrosion (in case of metal ladders) and structural failure. The load capacity requirements are specified in the OSHA standards for different ladders. Wooden ladders should be treated with clear preservative. Unsafe ladders should be tagged and removed from use, until repaired or discarded.

## **Improper Ladder Use**

Improper use of ladders is the cause of many accidents. The four principal causes of such accidents are:

- 1) Improper ascending, descending or working from ladders;
- 2) Instability of ladders due to improper positioning;
- 3) Structural failure due to overloading; and
- 4) Using ladders to carry materials, tools or equipment.

## **Ladder Safety**

To eliminate accidents associated with ladders the following measures must be taken (19):

- . Proper safety training and supervision must be instituted to assure compliance with the OSHA standards.
- . Ladders must be used with free hands, facing the ladder, and maintaining a three-point contact at all times (one hand and two feet or two hands and one foot).
- . The bottom of the ladder must be placed on a level, firm and unfrozen surface.
- . The ladder must be secured near the top or bottom to prevent slipping and excessive swaying.
- . The ladder must extend three feet above its top resting point and must be positioned so that the distance from the bottom of the ladder to the wall is one-quarter of the length of the wall.
- . Step ladders should be fully open when in use, and equipped with a spreader. Workers should not stand on the top few rungs of the ladder.
- . In cases where access is required for an appreciable length of time, adequately built temporary stairways should be used.
- . Metal ladders should not be used near electrical equipment and power lines.

### **Scaffolding Hazards**

Scaffolds are the most common means of performing work at heights. Main hazards are:

- . Falls from the scaffold;
- . Objects falling from the scaffold; and
- . Collapse of the scaffold.

These are mainly caused by environmental hazards, high winds, worker's loss of balance, or the deposition of excessive material, sometimes near the outer edges. Partial or total collapse of scaffolds can cause major injuries. This may be brought about by poor erection, defective materials and fittings, inadequate support or bracing, poor foundation, insufficient ties, and overloading.

### **Scaffolding Precautions**

Scaffolds are most susceptible to collapse during erection or dismantling. Some of the major precautions in controlling scaffold hazards are as follows:

- . The erection and dismantling of scaffolding should be carried out according to plans prepared by experienced persons.
- . The design of scaffolds should consider their purpose and location. In addition, scaffolds must be built from sound, strong and defect-free materials.
- . Scaffolds should be designed to carry four times their intended load which includes the workers, materials and the weight of the scaffold itself. Adequate footing to support posts, and lateral stability by diagonal bracing should be provided.
- . Scaffolds should be tied to the building to prevent movement of framework towards or away from the structure. Secured ladders and stairs for safe access and egress, and other safety features such as clearance near electrical lines, head protection, guard rails and toe boards should be provided according to the OSHA standards.
- . Overloading of the scaffold work platforms can lead to collapse, and should not be permitted. This is especially important during demolition where large pieces of material may drop or fall on the platform.
- . Dismantling scaffolds should be carried out under the supervision of experienced personnel, proceeding horizontally, in full width. Scaffolds should not be dismantled in vertical sections, and the detached members should not be stored on platforms.

### **Proper Housekeeping**

Proper housekeeping practices for maintaining scaffolds in safe working condition include daily inspections by an experienced and responsible person, use of communication signs (especially for incomplete structures) and keeping the structure clean, free from debris, tools, ice, snow, etc., before use. Scaffolding parts should be organized and stored in a dry and protected area. Scaffolds should be protected from collisions by vehicles and from open fires.

### **Suspended Scaffolds**

Suspended scaffolds are used for light, short-term work, such as painting and repair jobs on the exterior surface of a building. These scaffolds are suspended by fiber or wire ropes. The most common accidents with these devices are caused by rope or outrigger failures. Rope failures are generally due to excessive wear or damage that reduces their strength.

In the case of outriggers, improper placement may be responsible for failure. Suspended scaffolds should be inspected for defects, and ropes should have a safety factor of eight.

### **Elevating Work Platforms**

Mobile elevating work platforms provide a temporary support surface suitable for short duration tasks. Falls are the most common type of hazard associated with this equipment. Falls can be caused by the instability of the platform, or inadvertent movements caused by collision, obstruction, uneven ground, or overloading. Fall of materials and workers can be prevented by the following precautions:

- . Wear a safety harness at all times and attach it to a secure anchor point within the platform.
- . Prevent pedestrian access beneath working platforms.
- . Prevent accumulation of loose materials on the platform.
- . Avoid collisions.

### **Open Sides and Floor Openings**

Open sides and floor openings present a significant fall hazard on construction projects. When workers are exposed to fall hazards at elevations of six feet or more, appropriate safeguards must be incorporated into the work place. Falls may also occur near excavations or manholes when workers are entering or leaving the area, or when they simply may have not noticed the opening. In sewers, fall hazards may lead to drowning if the person experiences unconsciousness. The most effective means of fall protection on such locations are guard rails with toe boards, covers for openings, and hazard communication signs. Toe boards and screens are to be used to safeguard lower elevations from falling objects. Materials should not be placed near edges, where such protection is not provided. Prohibiting signs can warn workers against entering a fall hazard zone.

### **Steel Erection Fall Hazards**

Fall hazards are the greatest concern associated with steel erection operations. High risk steel erection activities include:

- . Rigging and connecting structural members, and decking;
- . Placement of roof framing members; and
- . The collapse of incomplete structural framework.

### **Safety Measures**

Preventing workers from falls during steel erection should concentrate on incorporating erection precautions in design and planning phases, and implementing active and passive protection systems. Provisions for fall protection equipment, safe access and egress for all work areas, and constructability issues (such as reducing the need to work at heights) should be addressed in design and planning. Other safety measures include:

- . Safety training, and establishing safety rules such as prohibiting column climbing, sliding, and beam walking;
- . Providing means for safe access, such as fixed ladders, scaffolds, and power-operated mobile work platforms; and
- . Providing fall arrest equipment.

## **Roofing Safety**

### *Sloping Roofs*

Roofing work causes a large number of fatal and serious fall injuries, particularly when work is performed on fragile materials (20). Flat roofs or low pitch roofs require edge protection and barriers. Sloping roofs, on the other hand, require crawling ladders or boards, which must be secured to prevent slipping. Also, a catch barrier or platform should be erected at eaves to catch and hold workers. Steep roofs (those with pitches greater than 50°) usually require a working platform.

### *Fragile Roofs, Skylights and Temporary Openings*

Fragile roofing materials are such as asbestos, glass and plastic may fail under the weight of the workers. The fragile or brittle nature of these materials may not be readily detectable, so warning signs must be posted to alert workers. Crawling boards and walkways should be provided for crossing such roofs. Sky lights and other temporary openings on roofs also expose workers to fall hazards. Temporary guardrails should be placed around such openings.

## **FALL PROTECTION DEVICES**

Fall protection measures must be used in situations where fall prevention methods such as platforms and guardrails are not feasible or practical, or the occurrence of falls is unavoidable.

### **Active vs. Passive Protection**

Fall protection devices eliminate physical injury by minimizing or eliminating the impact. Generally referred to as fall arrest equipment, they may be active or passive. Active protection equipment include items which are worn by workers to stop a fall, such as safety belts, harnesses and lanyards. In OSHA standards these devices have been collectively named "motion-stopping safety systems". Passive protection equipment are installed on the structure in order to stop the fall before impact. The primary example of passive protection is a safety net. Fall arrest equipment should be selected based on the task being performed.

### **Safety Belts, Harnesses and Lanyards**

Safety belts and harnesses are worn around the waist and attached by a lanyard to a secure anchor point (21). The body belt is equipped with a D-ring which is the link to the lanyard. A harness is a belt system that distributes the impact of the fall over the shoulders and holds the body upright in case of suspension. Some lanyards contain shock absorbers in the form of tear away sticking, stretch springs, or deforming metal strips. These can reduce the impact of the fall by absorbing the load's impact.

### **Safety Nets**

Safety nets consist of personnel nets and debris nets (1). They are passive fall protection systems installed within or on the periphery of structures to catch falling workers, and tools, or debris. They should be erected as close as possible to the working level. However, OSHA standards require that safety nets be installed no more than 25 feet below such working surfaces. Size of the net and the horizontal projection beyond the outermost edge of the building are critical. Nets should extend eight horizontal feet from the edge, and be sloped toward

the building to catch and hold falling objects and persons. The quality of nets, hardware and the connections must be checked and tested, and they must conform to the OSHA standards. Ropes should be made of No.1 grade pure manila and nylon, and should meet OSHA's impact resistance requirements. Fall arrest equipment should be used only if fall prevention is not possible. They are only effective if used properly and maintained in good condition.

## APPLICABLE OSHA STANDARDS

OSHA standards pertinent to fall protection are presented in Table V-8.

**Table V-8**  
**OSHA Standards on Fall Protection**

### 29 CFR 1926 Subpart L-Ladders and Scaffolding

#### Subpart M-Floor and Wall Openings

Section	Topic
1926.431	Scaffolding
1926.453	Manually propelled mobile ladder stands and scaffolds
1926.500	Guardrails, handrails, and covers

### 29 CFR 1910 Subpart D - Walking - Working Surfaces

Section	Topic
1910.22	General requirements
1910.23	Guarding floor and wall openings and holes
1910.24	Fixed industrial stairs
1910.25	Portable wood ladders
1910.26	Portable metal ladders
1910.27	Fixed ladders
1910.28	Safety requirements for scaffolding
1910.29	Manually propelled mobile ladder stands and scaffolds (towers)
1910.30	Other working surfaces

### 29 CFR 1926 Subpart E-Personal Protective and Life Saving Equipment

Section	Topic
1926.95	Criteria for personal protective equipment
1926.96	Occupational foot protection
1926.97	Protective clothing for fire brigades
1926.98	Respiratory protection for fire brigades
1926.100	Head protection
1926.101	Hearing protection
1926.102	Eye and face protection
1926.103	Respiratory protection
1926.104	Safety belts, lifelines, and lanyards
1926.105	Safety nets
1926.106	Working over or near water

## CRANES, DERRICKS AND HOISTS

Cranes, derricks and hoists are machines that move heavy loads of construction materials and equipment over a limited area. This movement can be vertical or horizontal. There are many types of cranes (22). Four major types are described below.

### Mobile Mechanical Crane

A mobile mechanical crane has a rigid mechanical drive from its power plant through the transmissions, chains, gears and shafts. The basic

crane motions are the raising and lowering of the load by raising and lowering the crane boom, and swinging the load by rotating the crane body. The boom is the main component of the crane. It is a long, structurally reinforced beam consisting of three or four connected chords. Another section, which is known as the "jib", is mounted on top of the boom in order to extend the reach; however, this occurs at reduced load capacity. The operator controls the motion and the hoist, mechanically or hydraulically. A mobile crane can be mounted on a conventional truck or on other wheel-top carriers.

### **Mobile Hydraulic Crane**

Mobile hydraulic cranes function similarly to mechanical cranes. The motions and the power of this type of crane, however, are controlled by hydraulic pumps which supply pressure by actuating cylinders or hydraulic motors.

### **Tower Crane**

A tower crane is primarily used for high rise construction or on projects where great mobility is not required. A tower crane consists of a cantilevered horizontal boom that is connected to a fixed tower. The tower is supported by other structures and sits on a foundation. The load is suspended from a trolley which traverses the length of the boom and gives greater flexibility to the movements of the load. The height of the tower crane can be extended to accommodate the building requirements during construction.

### **Bridge Crane**

Bridge cranes mainly consist of two types: overhead cranes and gantry cranes. In the overhead type the load is supported by a bridge structure equipped with a track on which a hoist system can move. The bridge is commonly fixed to the building itself. In the gantry crane a pulley is suspended from a trolley that can travel along a bridge-like structure. The ends of this structure, however, rest on upright towers that move on rubber tires (for construction sites). Some gantry cranes with rotating bodies can serve circular spaces, where one end is free to circle the crane.

### **Derricks**

Derricks are hoisting machines which consist of a mast and a slanted boom (22). There are two types of derricks, one supported by guy lines and the other by stiff legs. The boom may be fixed or it might rotate. Derricks can be mobile or fixed. A winch (a cylinder or drum around which a chord of sling is coiled) attached to the mast provides the lifting action by coiling the tackle through the boom hoist to which a hook is connected. The boom and the mast can fully rotate depending on the design.

### **Hoists**

A material hoist is another common mechanical device, used for moving heavy loads (1). It lifts directly from above the load. It is primarily used for raising and lowering loads, while the material is suspended. However, a hoist can also move objects horizontally. Hoists consist of sheaves (grooved wheels) that change the direction or

point of application of the force. Hoists can be operated manually, electrically or pneumatically.

## **Crane Hazards**

The majority of crane accidents are caused by operational errors and lack of planning. The main operational hazards on construction sites are:

- . Overturning of the crane;
- . Structural failure;
- . Dropping the suspended load;
- . Electrocution; and
- . Incorrect erection, modification and dismantling procedures.

## **Overloading**

Overturning of the crane and structural failure can be caused by overloading, instability of the soil, improper placing and bracing of outriggers, and sinking of outriggers into the ground. Overloading can cause crane tipping, or damage the strength of jibs and hoist ropes, leading to structural failure without any warning. Overloading may occur when allowable radius for the load is exceeded. Other causes of overloading are snatching of the load (from rest or from rapid deceleration of suspended loads), dragging the load on the ground (which increases the load due to frictional forces), eccentric lifting, wind effects on suspended loads with large surfaces, and deflection of the jib when the suspension ropes are stretched. Dropping the suspended load is usually due to incorrect slinging. The cause may be defective chains, slings and lifting gear, or the loads exceeding the limits. Dropping the load may also be caused by a collision between the load and a structure, or the crane itself.

## **Electrocution**

Electrocution is also a potential hazard when the crane is operating in the vicinity of overhead power lines. Contact with the line will conduct the electric charge into the body of the crane and ultimately to the crane operator and the workers who may contact the crane.

## **Crane and Derrick Stability**

There are specific stability hazards associated with specific crane types. In the case of mobile cranes, site gradient and soil composition are critical for stability. Slopes as low as one percent can affect the stability and capacity of a crane. Outriggers are commonly used in mobile cranes to increase the base area. However, if the outriggers are not fully extended or not pinned in position, they are not effective, especially if the supporting soil is soft. Tower cranes are particularly vulnerable to lateral forces and foundation instability. Inadequate foundation support can cause a collapse. Vertical and horizontal loads, swinging moments and overturning moments may exceed design limits causing loss of balance. Strong winds on travelling tower cranes as well as stationary cranes can upset the balance and cause overturning. Guy derricks and stiff leg derricks are also susceptible to overturning. The angle between the legs and the mast or the guy wires and mast is especially critical to stability.

## **Hoist Hazards**

Major factors affecting the safe use of hoists are design and operating conditions; operators' skill and knowledge, and proper rigging practices. Accidents associated with hoists results from: (a) failure of attachment devices during a lift resulting in dropped loads; (b) collision with persons or objects as consequences of uncontrolled movement of the hoists or loads; (c) contacts occurring to personnel in work area, while loads are being attached; and (d) failure of the structural or mechanical parts of hoists during lifting or moving loads (23).

## **Hazard Control for Cranes and Hoists**

Advance planning of the lifting operations by cranes and hoists, and the proper maintenance of the lifting equipment are the two key factors in eliminating the hazardous conditions from these operations. Advanced planning should include:

### **Advanced Planning**

- . Selection of trained and able workers, and briefing them about the operation;
- . Organizing the sequence and the process of the lifting operation;
- . Identifying the correct lifting position with respect to weight and center of gravity;
- . Establishing the maximum lift height and radius to which the load will be taken;
- . Selection of appropriate crane and lifting gear for the job;
- . Preparation of the path of moving loads, the routes to be taken by mobile cranes;
- . Elimination of the obstruction, excavation and electrical hazards; assessing the soil bearing capacity; and
- . Scheduling activities properly to avoid conflict of operations and work under suspended loads.

## **Precautions During Crane Operations**

The following precautions are recommended during crane operations:

- . Assure that the suspended load does not exceed the rated capacity of the crane;
- . Assure that outriggers used in all lifting operations are equally and fully extended;
- . Keep the crane operation a safe distance from the edge of excavations and electrical power lines. One should be prepared to disconnect the electrical supply in case of contact between the crane boom and a power line. The operator should be instructed to remain in the cab, or jump out of the cab without touching the body of the crane to avoid electrocution.

Height precautions are especially critical to tower cranes. Safe access to the cab and the jib are important to prevent falls.

## **Maintenance and Inspection**

Maintenance is extremely important in securing the safety of machinery and equipment. OSHA standards require inspection of all machinery before each use. Results of tests and inspections should be recorded. Frequent inspections should be made on wire ropes and guys, hoists and trolley cables, jib and counter weight jib guy lines, hoist rope anchorage on winding drum, foundations, and structural connections.

## **Additional Safety Precautions for Cranes and Hoists**

The following additional safety precautions have been recommended by CECS (24) for crane and hoisting operations:

- . Assure that cranes meet applicable governmental and voluntary standards.

- . Post rated load capacity charts, recommended operating speeds, special warning hazards, and other essential information on cranes and ancillary equipment.
- . Assure cranes allow for proper access, unobstructed operator view, ergonomically placed controls with suitable locking devices, protection against the weather, and fire protection.
- . Have competent persons supervise the placement, erection, and dismantling of cranes.
- . Inspect the cranes, their components, and rigging prior to use, before a new shift, or under changing conditions, such as, overstressing, ground movement, etc.
- . Assure that only qualified and competent individuals, well-versed in cranes, and hoists are allowed to operate and maintain the equipment.
- . Confirm the competency of rigging personnel involved in lift operations.
- . Allow only authorized personnel engaged in hoisting operations in lift areas.
- . Supply hoists specifically designed to handle the maximum anticipated load.
- . Require the safe load capacity and safe operating procedures to be labelled on each hoist.
- . Confirm that all hoists are properly installed and tested prior to initial use. Assure hoist supports have an adequate design factor for the maximum loads to be imposed (including weight of hoists/rigging).
- . Determine the weight of the load to be lifted keeping within the structural/stability limitations.
- . Make sure the hoist and load hitch are centered above the load.
- . Assure load attachments are secure and within capacity prior to the lift.
- . Make smooth lifts and movements to assure that the loads do not jerk and fall.
- . Report problems in equipment structure or functions.
- . Secure the cranes and store the rigging equipment properly when not in use.
- . Maintain communication during lifts using proper signals.

## APPLICABLE OSHA STANDARDS

Table V-9 lists the OSHA standard (29 CFR 1926 Subpart N) associated with cranes, derricks and hoists. Elevators and conveyors are also included in this subpart, but have not been elaborated on herein.

**Table V-9  
29 CFR 1926 Subpart N-Cranes, Derricks,  
Hoists, Elevators, and Conveyors**

<u>Section</u>	<u>Topic</u>
1926.550	Cranes and derricks
1926.551	Helicopters
1926.552	Material hoists, personnel hoists, and elevators
1926.553	Base-mounted drum hoists
1926.554	Overhead hoists
1926.555	Conveyors
1926.556	Aerial lifts

## **HEAVY CONSTRUCTION EQUIPMENT**

Heavy construction equipment is an integral part of construction operations. The machinery is used for many demanding tasks that are beyond human capability. Earth moving equipment such as bulldozers, scrapers, motor graders, and front-end loaders are typical of the heavy construction equipment which perform cutting, transporting and grading.

### **Bulldozers, Scrapers, Graders and Loaders**

**Bulldozers** are used to strip soil in layers. They move and grade earth/rock material for distances less than 300 feet. Types are bulldozers and angle dozers. **Scrapers** also strip in layers. However, they also load the earth into bowls, and haul, spread, and partially compact it. Types are crawler-tractor-pulled scrapers, and wheel-tractor-pulled scrapers. They represent a compromise between best backing and best hauling machines. **Motor Graders** cut, shape and grade. They have a blade that can be set at different angles. They can be quite versatile when fitted with rippers, backslopers, snow plows, etc. **Front-End Loaders** are used to transport bulk materials, to load trucks, to excavate earth, etc. Types are crawler and wheel loaders. Other heavy construction equipment such as hydraulic excavators, trenching machines, tractors and rollers are not covered in this module. Relevant information can be found in reference (1).

### **Heavy Equipment Safety Hazards**

There are many hazards associated with the heavy construction equipment that are common to all. These may be listed as:

- . Poor repairs and service;
- . Obstructed view in backing;
- . Striking people and collision with other equipment;
- . Travelling empty at excessive speeds;
- . Pinch points between equipment and objects;
- . Riders falling from equipment or bucket;
- . Overturning of the equipment;
- . Unexpected electrical shock;
- . Failure of lifting mechanisms/operational failures;
- . Injuries to operators due to ingress/egress difficulties;
- . Runaway machines (not blocking wheels upon parking or operator inability to control); and
- . Being struck by limbs of trees or other overhead obstructions, and moving equipment.

### **General Safety Precautions**

It is possible to list some general as well as specific safety precautions associated with heavy construction equipment. Recommendations for general precautions are as follows:

- . Management should carefully select competent operators.
- . Rules should be clearly set for operation.
- . All equipment should be kept in good working condition.
- . All new machines should be equipped with rollover protection.
- . Existing machines with rollover protection should be maintained in working condition.
- . Adequate illumination should be provided for night operations.

- . Dust must be kept down on all roads.
- . Operators must be given clear and specific instructions.
- . All personnel should be clear of the work area.
- . Unauthorized riding on the equipment should be prohibited.
- . Speeds should be consistent with job conditions and OSHA requirements.
- . Signal person is needed in busy areas.
- . Equipment should have an audible reverse signal alarm system which will operate automatically with backward movement.
- . Repairs should be done when the machine is not running.
- . During refuelling operations, all personnel in the vicinity should stop all motors and refrain from smoking.
- . Personal protective equipment (hard hat, steel toed shoes, gloves, safety glasses, respirators, etc.) should be used at all times.

### **Bulldozer Precautions**

Specific precautions for specific equipment are also available. Typical bulldozer precautions are given below:

- . On steep grades, the blade should be lowered to secure a load, and should not be jammed into the earth (this may cause overturning).
- . To avoid overturning in filling operations, bulldozers should not get too close to the edge, and side hill travel should be avoided.
- . When coupling a tractor to another piece of equipment, the bulldozer should be stopped, put in neutral gear and the brakes should be set before a person is allowed to couple the equipment.
- . Master clutch should be disengaged, engine idled, and brakes locked when receiving a wire rope on a drum or through sheaves.

### **Scraper Precautions**

Important scraper precautions are:

- . During downhill motion, scraper should remain in gear to prevent speeding and brakes should be used to control speed.
- . Sharp down hill turns and turns top heavy with the apron up should be avoided.
- . Bowls should be blocked up when blades are being replaced.

### **Motor Grader Precautions**

Typical safety precautions for motor graders are listed below:

- . The equipment should not be used on slopes greater than 45 degrees to avoid overturning.
- . When operating on highways, graders should be kept to the right side of the roadway. Flagmen should warn traffic and warning devices such as flags, flashing red lights, and the "slow moving vehicle" emblem should be properly displayed.
- . The blade should be extended when scraping shoulders to prevent overturning.
- . Operators should be aware of rocks, logs, trees when sloping banks.

### **Front-end Loader Precautions**

Some typical front-end loader precautions are as follows:

- . Prohibit unauthorized riding or use;
- . Maintain speed limits as required by OSHA.
- . Prohibit jumping from or climbing on the equipment while it is in motion.

### **Training**

Training of workers on all cases is essential, and must include a review of potential hazards and familiarization with the equipment.

## **APPLICABLE OSHA STANDARDS**

The OSHA standards for heavy construction equipment are covered in 29 CFR 1926 subparts N and W, which also include the standards for motor vehicles. Table V-10 groups them together, although safety information on motor vehicles will be provided separately in the next section.

**Table V-10  
OSHA Standards for Heavy Construction Equipment  
and Motor Vehicles**

### **29 CFR 1926 Subpart O-Motor Vehicles, Mechanized Equipment and Marine Operations**

<b>Section</b>	<b>Topic</b>
1926.600	Equipment
1926.601	Motor vehicles
1926.602	Material handling equipment
1926.603	Pile driving equipment
1926.604	Site clearing
1926.605	Marine operations and equipment

### **29 CFR 1926 Subpart W-Rollover Protective Structures; Overhead Protection**

<b>Section</b>	<b>Topic</b>
1926.1000	Rollover protective structures (ROPS) for material handling equipment
1926.1001	Minimum performance criteria for rollover protective structures for designated scrapers, loaders, dozers, graders, and crawler tractors
1926.1002	Protective frame (ROPS) test procedures and performance requirements for wheel-type agricultural and industrial tractors used in construction
1926.1003	Overhead protection for operators of agricultural and industrial tractors

## **MOTOR VEHICLES**

Transporting material and personnel on and around construction sites, especially on large, complex projects, require special attention to traffic operations and vehicle related safety hazards. Numerous injuries and fatalities occur because of mishaps involving construction vehicles on and off the construction project sites. On site aspects are the primary focus on herein.

### **Safety Hazards**

Mishaps occur during loading and unloading operations, during mounting and dismounting of personnel, from collisions between the vehicles or between vehicles and fixed objects (e.g. temporary and permanent structures), from run-away vehicles, and from vehicles running over people or striking them. Overturning of vehicles caused by steep terrain, earth slides, improper loading or overloading of the vehicles, unsafe vehicles, and driver errors are the other common motor vehicle hazards. The absence of law enforcement on private construction sites may encourage unsafe and reckless practices, such as riding vehicles at high speeds or jumping off the vehicles while in motion. Lack of planning for an effective site transportation system, failure to supervise the traffic operations, improper maintenance practices and lack of adequate training efforts are fundamental

## **Safety Precautions**

contributors to motor vehicle safety problems on construction sites.

Safety precautions for construction motor vehicles can be listed as follows (1):

- . Establish a site traffic system which includes the planning of routes and installation of appropriate traffic and hazard signs.
- . Segregate vehicles from the pedestrians and construction activities by means of physical barriers wherever possible.
- . Restrict the traffic movement to assigned routes, parking and loading areas.
- . Provide adequate width to allow for safe movements (turning at corners, etc.).
- . Communicate site hazards such as excavations, rough terrain, underground utilities and other obstructions to all concerned personnel.
- . Provide adequate lighting for motor vehicle routes and work areas.
- . Maximize one-way traffic operation, and eliminate vehicular and pedestrian crossings.
- . Minimize reverse motion of the vehicles; prohibit construction activities from areas where vehicles have to reverse; use audible warning and/or signal person when reversing is necessary.
- . Maintain the construction roads in safe condition, and grade regularly.
- . Assure the competence of drivers.
- . Enforce speed limits and traffic regulations on the construction site.
- . Train and supervise all employees with regard to the hazards of site traffic.
- . Assure that the employees do not ride vehicles in unsecured positions, or ride in vehicles which are not designed for transport of personnel.
- . Prohibit overloading; properly block vehicles while loading.
- . Instruct drivers not to remain in cab while the vehicle is being unloaded.
- . Perform routine inspections on the vehicles for mechanical safety (e.g. the steering wheel, brakes, and emergency brakes); keep all windows clean for good visibility.

## **APPLICABLE OSHA STANDARDS**

29 CFR 1926 Subpart O, which is also presented in Table V-10 covers motor vehicle safety.

## **HAND AND POWER TOOLS**

Hand tools are used in a great number of construction activities, from formwork erection to finishing of dry wall and installing hardware. Hand tools may be classified under three categories: manual tools, power hand tools, and powder actuated hand tools. The first class of tools are those that are manually operated; they include common tools like hammers, wrenches, saws, etc. Power hand tools are portable tools which are energized by electricity, gasoline, or compressed air. The

powder actuated tools utilize explosive charges to drive fasteners into position. These tools do not require an independent power source, and can be used without cables. Powder actuated tools are of two basic types: direct-acting and indirect-acting. In the first case, the expanding (explosive) gas force acts directly on the fastener, driving it along the barrel. In indirect-acting tools the gas force acts on a captive piston which in turn drives the fastener into position. There are three classes of powder actuated tools based on power and velocity. These are low velocity class tools with a test velocity of 300 feet per second; medium velocity class tools with a test velocity between 300 feet and 500 feet per second; and high velocity class tools with a test velocity over 500 feet per second. The most common powder actuated tools are of the low velocity class, and of the indirect type. Some tools include provisions for varying the velocity. Safe work practices associated with the use of hand, power, and powder actuated tools are covered in AGC's Manual of Accident Prevention in Construction (1).

#### **Manual Tool Hazards**

Hazards associated with manual hand tools can be caused by poor maintenance, poor housekeeping and improper use. Some of these hazards are:

- . Using damaged tools (examples are defective handles in hammers and saws, and worn-out wrench teeth which can cause slippage);
- . Poor housekeeping and improper storage, which can expose sharp edges and create tripping hazards;
- . Electrocution hazards caused by metallic tools (metals are good conductors of electricity);
- . Misuse of tools, or using tools for wrong tasks; and
- . Foreign body in the eye, which is a common injury due to lack of eye protection while operating or sharpening the tool.

#### **Electric Tool Hazards**

Portable electric hand tools are very popular on construction sites. Most accidents involving these tools are due to damage or internal defects, and improper grounding (or no grounding). Other accidents are caused by defective insulation of the connecting cables, faults and defects in conductors, defective enclosures, and damaged receptacles and sockets. Many of these defects can cause electrocutions. Defects in these tools may be due to overworking, overheating, or damage to insulation or grounding. Damaged cords have been the cause of many construction accidents. Reverse polarity in wiring (the reversal of hot and neutral wires) can also cause electrocution. Use of electric tools in wet areas exposes the operator to shock hazards.

#### **Sawing Hazards**

A variety of saws are used in many construction operations such as carpentry, concrete work, cutting masonry, etc. Power saws are commonly used for these operations. There are four basic types of saws: portable hand saws; table or bench saws; swing cut-off saws; and chain saws. Some hazards associated with all of these types of saws are as follows:

- . Poorly maintained saws may lack fixed guards over the blades, and the blades may not be adequately secured.
- . During use, material being cut may not be adequately supported.
- . Dust inhalation can be a problem.
- . Operator distraction can cause accidents.
- . Foreign objects (such as nails) in the material can shatter and fly in pieces upon contact with the blade, and injure the operator.

### **Hazards of Other Power Tools**

Other power tools such as drills, grinders and sanders also present hazards to the operators. The most common hazard is the generation of flying particles during grinding, which can cause injury, particularly to the eye. Overspeeding and incorrect mounting of wheels on grinders can crack the wheel while it is rotating. This cracking could lead to wheel bursting, which could injure the operators.

### **Powder Actuated Tool Hazards**

Powder actuated tools operate with great force, and are potentially lethal. Inadequate training, incompetent and irresponsible use are the primary factors contributing to hazardous conditions. Basic hazards associated with powder actuated tools include:

- . Attempting to use the tool on unsuitable materials;
- . Thorough penetration caused by excessive velocity, changes in the consistency of material penetrated, or voids in the material;
- . Ricochet caused by positioning the fasteners into very hard materials or near the edges;
- . Spalling of the material (e.g. in concrete spalling is caused by the initial compressive impact.)
- . Misfiring; and
- . Operating near explosive materials.

### **Hazard Control for Hand and Power Tools**

All tools should be kept in safe working condition, stored properly in suitable containers, and protected against corrosion. Adjustable parts should be lubricated to prevent wear and misalignment. Tools should be maintained regularly. Damaged tools should not be kept on the jobsite, and should be repaired properly. Personal protective equipment should be used during tool use, the choice depending on the nature of the task. Eye protection, safety helmets, gloves, steel toed shoes, respirators, etc. are effective shields from injury. Tools should be properly selected for the particular operation. For example, manual saws should be selected based on shape and size with correct teeth for the size of cut and the material being cut.

### **Electric Tool Safety**

All tools should be equipped with adequate guards and safety devices. Electric tools should be equipped with ground fault circuit interrupters. Extension cords should be durable and be weather proofed. Cords should be rated for outdoor use, but should still be kept away from water, since moisture can seep into insulation. Cords should be inspected to ensure that the entire length of insulation is intact and the plug pins are not damaged. All tools must use a three-wire cord with a grounding plug.

## **Work Environment**

The work environment should have sufficient unobstructed space and adequate lighting around the tool. Adequate ventilation (to eliminate or minimize hazardous dust or fumes) should be provided at all times. With the exception of those which are hand-held, tools should be properly fixed, using non-kickback attachments to avoid movement during operation. Saws should not be in motion except during cutting. Blades should be sharp, securely fitted to rotate in the correct direction.

## **Powder Actuated Tool Safety**

To avoid hazards and injuries resulting from powder actuated tools the operators must guard against misuse. Tools should not be loaded until the operator is ready to use them. They should be unloaded when the tool is carried around, and most importantly, they should not be pointed at others. To avoid thorough penetration, spalling, edge failure, and ricochets, the material receiving the fastener should be examined in terms of consistency, density and compressive strength. After examining the material, the most suitable velocity, fastener size and location should be determined. Stable footing and platforms should always be provided particularly when working at elevations. In case of misfires, the tool should be pressed against a surface for at least 30 seconds to allow for delayed detonation. Cartridges that have misfired should be removed and stored in a metal box. Powder actuated tools should only be issued to trained operators. They should be stored in a dry and cool place and access to them should be controlled.

## **Training**

Most accidents created by hand and power tools can be minimized through adequate training. No worker should operate any tools without proper training in their safe use. The training program must stress not only the technical details as recommended by the manufacturer, but also clarify that powder actuated tools can be lethal.

## **APPLICABLE OSHA STANDARDS**

OSHA standards dealing with hand and power tools are presented in Table V-11.

**Table V-11  
OSHA Standards on Hand and Power Tools**

### **29 CFR 1926 Subpart I - Tools - Hand and Power**

<u>Section</u>	<u>Topic</u>
1926.300	General requirements
1926.301	Hand tools
1926.302	Power-operated hand tools
1926.303	Abrasive wheels and tools
1926.304	Woodworking tools
1926.305	Jacks-lever and ratchet, screw and hydraulic
1926.306	Air receivers
1926.307	Mechanical power-transmission apparatus

### **29 CFR 1910 Subpart P - Hand and Portable Powered Tools and Other Hand-Held Equipment**

<u>Section</u>	<u>Topic</u>
1910.242	Hand and portable powered tools and equipment, general
1910.243	Guarding of portable powered tools
1910.244	Other portable tools and equipment

## **ELECTRICAL WORK**

Electricity is present in almost every aspect of the building environment. Aside from post occupancy needs, electricity is an integral part of the construction process. It is used for site illumination, and as a source of power for energizing various tools and equipment. CECS (25) has presented some useful information on electrical safety, which is summarized in the following paragraphs.

### **Electrical Hazards**

Electricity is dangerous because it rarely gives any advance warning of its potential danger. Unlike other hazards, electricity can not be seen or heard; therefore unintended human contact is always a possibility. Electric shock is a major hazard and its severity depends on the amount of current, duration of the contact, and route of entry. Shocks with high levels of electricity (amperage and voltage) can cause fibrillation of the heart which may lead to death; however, small currents can also be lethal. Electrocution is one of the most common causes of construction related fatalities. Electric shocks cause external burns and internal damage, muscle contractions, and loss of balance which can lead to falls from elevations.

### **Overhead and Underground Cables**

Overhead power lines and underground cables are the basic means of electric supply and distribution. Generally, high voltage electricity is routed on uninsulated overhead lines. If equipment booms come in contact with overhead power lines, electric arcs may travel a considerable distance and expose workers to the risk of electrocution. Underground cables can be damaged during excavation operations. In cases where machine operators come in contact with underground cables, fatal injuries are possible.

### **Receptacles, Connectors and Grounding**

Receptacles and connectors are the most common means of electrical distribution. Damaged or defective receptacles and connectors are hidden hazards, since they can energize metal components. Improper grounding and temporary wiring can also cause electric shocks. Lack of proper grounding results in shocks from internal current leakage to the enclosure of equipment. A person coming in contact with the equipment provides a path for the electric current. Workers holding tools usually experience a tightening of the grip allowing more current to flow, increasing the danger of electrocution. This is because the involuntary muscle contraction extends the time the person is in contact with the current.

### **Site Distribution Systems**

Site distribution systems provide power to energize electrical equipment, and site illumination. Much of the wiring will be temporary; however, makeshift installations with poor workmanship, inferior materials, and

inadequate safeguards create electrocution hazards.

**Other  
Common  
Hazards**

Other common hazards in electrical work include:

- . Unsafe installation operations, such as poor splicing;
- . Faulty insulations;
- . Overloading of conductors;
- . Electric current in wet and moist areas;
- . Fire hazards associated with generated heat;
- . Vehicular collision with outdoor electrical equipment;
- . Access to live parts by unqualified personnel; and
- . Inadequate work space around electrical equipment.

**Electrical  
Hazard Control**

Some practical steps can prevent the danger of electric shocks to construction workers. These are described in the following paragraphs.

**Overhead Cable  
Precautions**

To avoid contact with overhead cables, crane operations should be kept away from power lines a minimum distance of ten feet or more depending on voltage rating of the line. Suitable barriers such as posts, tension wires and earth banks should be placed at points where overhead cables present a hazard. When working beneath the overhead cable is unavoidable, precautions must be taken to prevent contact between the cables and ladders, scaffold poles, and construction equipment. It is particularly important that a person observe the equipment clearance from power lines and warn the operators of possible hazards.

**Underground Cable  
Precautions**

The foremost precaution in underground cables is the correct identification of all installation locations, routes, depths, and voltage. Before commencement of excavation work, the local electric company or an authorized state agency must be consulted. All buried cables should be considered live and lethal. Hand digging should replace power and metal tools when workers are nearing the assumed cable location.

**Grounding  
Precautions**

Effective grounding is a procedure that prevents harmful voltage leakage between electrical enclosures and their surroundings. This is generally accomplished by connecting all electrical enclosures together, by connecting the complete electrical installation to its surrounding, and by providing a low impedance path from every enclosure back to the service entrance. These steps reduce the intensity of shock. Also, a grounding conductor must connect the equipment enclosure to the receptacle and to the service entrance. Damaged wiring and improperly installed grounding conductors are ineffective and dangerous. Consequently, a device known as "ground fault circuit interrupter"

(GFCI) has been developed to constantly monitor the flow of current through the branch circuit conductor. This device will detect even a small amount of current that would not trip fuses and circuit breakers. A GFCI detects leakage in tools, and allows the current to flow to the ground.

### **Other Precautions**

Other precautions to assure safe electrical work are as follows:

- . Wiring with appropriate insulation and adequate current carrying capacity should be used to prevent overload and heating.
- . Switches, fuses, circuit breakers and other control devices should be enclosed and grounded.
- . Site illumination should provide adequate light for safe working conditions. Temporary lights should be positioned as high as possible, and the light poles and high posts should be secured. Special attention should be given to the illumination of critical areas such as floor openings, tunnels and shafts, and stairways. Portable lights should have insulated handles, lamp cages and enclosed wiring.
- . High voltage power lines (440 volts or higher) should have adequate vertical clearance.
- . Live electrical parts should be guarded to prevent accidental contact.
- . Electrical installations in wet or damp areas (excavations and trenches) should be placed on dry areas where workers can stand. Non-metallic items should be used, wherever possible.
- . Exposure of electrical installations to explosive and flammable materials should be prevented. Switches, circuit breakers, and other control devices should not be installed near such materials; if unavoidable, special parts should be used.

### **Safety Program**

As a general safety measure, a comprehensive safety program should be established. This program should emphasize training on the hazards of electricity, and should include routine inspections by qualified persons. An effective maintenance program should be instituted to identify and correct the problems. Access to live electrical parts should be restricted to qualified personnel only, and a hazard communication program should be established to identify the hazards associated with electrical equipment. All circuits should be marked to indicate their voltage and intended use. High voltage junction boxes, and transformers should be clearly marked with warning signs. Many subcontractors utilize on-site electric installations to perform their tasks (HVAC subcontractors, communication subcontractors etc.) Supervisors must monitor these activities to assure safe practices, especially on alteration work.

### **First Aid**

First aid treatment may be required if a worker receives an electrical shock. The current should be switched off before touching the victim. If this is not possible, the victim should be freed using heavy duty insulating gloves or other insulated material. Resuscitation may be applied if necessary.

## APPLICABLE OSHA STANDARDS

Table V-12 covers OSHA's standards on electrical safety.

**Table V-12**  
**OSHA Standards on Electrical Safety**

29 CFR 1926 Subpart K-Electrical	
Section	Topic
1926.403	General requirements
1926.404	Wiring design and protection
1926.405	Wiring methods, components, and equipment for general use
1926.406	Specific purpose equipment and installations
1926.407	Hazardous (classified) locations
1926.408	Special systems
1926.416	General requirements
1926.417	Lockout and tagging of circuits
1926.431	Maintenance of equipment
1926.432	Environmental deterioration of equipment
1926.441	Batteries and battery charging
29 CFR 1910 Subpart S - Electrical	
Section	Topic
1910.302	Electric utilization systems
1910.303	General requirements
1910.304	Wiring design and protection
1910.305	Wiring methods, components, and equipment for general use
1910.306	Specific purpose equipment and installations
1910.307	Hazardous (classified) locations
1910.308	Special systems
1910.332	Training
1910.333	Selection and use of work practices
1910.334	Use of equipment
1910.335	Safeguards for personnel protection
29 CFR 1926 Subpart V-Power Transmission and Distribution	
Section	Topic
1926.950	General requirements
1926.951	Tools and protective equipment
1926.952	Mechanical equipment
1926.953	Material handling
1926.954	Grounding for protection of employee
1926.955	Overhead lines
1926.956	Underground lines
1926.957	Construction in energized substations
1926.958	External load helicopters
1926.959	Lineman's body belts, safety straps, and lanyards

## EXCAVATION AND TRENCHING

Excavation and trenching operations are essential to many types of construction projects. Foundations, drains, sewers, and underground utilities are part of a great majority of construction projects, requiring excavation or trenching. Excavation is the removal of soil and rock from the original location. The behavior of soil during excavation is dependent on its composition and the environmental conditions. Soil composition varies, from sand which flows easily, through silt to clay which is cohesive. Water is often present in soil to some degree and affects soil behavior. Many types of soils can not support their own weight during excavation. Therefore, some form of support is often

required. The exact method of support will depend on the soil type, as well as site and ground water conditions. In shallow trenches, or excavations with depths less than five feet, sloping or shoring may not be required if the soil is cohesive. For deeper trenches, support will be required as decided by a qualified person.

### **Excavation and Trenching Hazards**

Detailed information on excavation and trenching hazards has been presented by CECS (26). The primary hazard in excavation operations is the possibility of cave-ins, or earth slides, burying workers in the trenches. Many of these accidents result in death. Persons buried beneath the soil become unable to breath and ultimately suffocate. Complete burial is, in fact, not necessary to cause death. Pressure of surrounding soil will force air from lungs and prevent further breathing. The likelihood of rescuing buried workers in such cases is usually not very high because heavy equipment can not be used to uncover victims for fear of causing further injuries. Furthermore, sending rescuers inside a caved-in trench exposes more persons to the same danger.

### **Factors Causing Cave-ins**

The four important factors that contribute to cave-ins are as follows:

- 1) **Weight:** Weight is generated by the soil itself, construction equipment and vehicles, or other objects.
- 2) **The amount of water in soil:** excessive moisture or lack of moisture can weaken the soil leading to collapse.
- 3) **Vibrations:** Vibrations are caused by activities such as vehicular traffic, blasting and pile driving.
- 4) **Soil composition:** The composition and structure of the soil affects its stability during the excavation process. Mechanical failure due to removal of lateral support is also a critical factor in cave-ins.

### **Effects of Water, Traffic and Surcharge Loads**

Water, either by rain or percolation, can effect the lateral resistance of soil. Water can enter the dry soil through cracks and voids and cause softening and sudden loss of strength. In cold climates freezing and thawing can affect soil strength. Water can also increase the weight of soil, and act as a lubricant contributing to slippage. Vehicle traffic, especially large trucks and operation of heavy construction equipment can cause soil displacement and instability. Other hazardous conditions are created by placing excavated earth, pipes and shoring equipment too close to the trench to form additional (surcharge) loads. Impacts during unloading of these materials can lead to cave-ins as well.

### **Previous Excavations**

There are certain excavation hazards that may be particular to a specific location, such as a trenching operation at or near previously excavated ground. Excavation reduces the inherent strength of the soil. Therefore, starting a new excavation on previously excavated ground increases the possibility of a cave-in. Where new excavation is planned close or parallel to a previously excavated trench, it must be recognized that the ground between them may be particularly susceptible to collapse. Hazards are also caused by differing strata within a soil cut,

or by pockets of weak soil at the site. Existing vegetation such as large trees extract the soil moisture through their roots and may contribute to loss of soil strength.

#### **Adjacent Structures**

One of the greatest hazards encountered during excavation is the collapse of adjacent structures which can result in catastrophes and fatal injuries. In construction projects involving proposed additions and renovations a new trench is commonly excavated close to an existing foundation wall. If the soil is removed to a depth that is equal to or greater than the depth of the existing footing, and proper shoring is not provided to support the existing structure, the loss of bearing support of the excavated soil may cause a partial or full collapse of the existing structure.

#### **Other Hazards**

Although cave-in failures are generally the major concern in excavation operations, other hazards may also be encountered. Excavations are performed for a variety of purposes and they involve a variety of activities. Physical injury from falls or falling objects, exposure to buried electrical cables, and hazards associated with confined spaces are also of major concern, and should not be overlooked.

#### **Hazard Control**

Excavation cave-ins are preventable if certain precautionary measures are adopted. It is important to recognize that visual inspection of soil stability is not sufficient to assure the long-term safety of an excavation because one can not anticipate the changes in the weather, rainfall, or future unsafe practices. Therefore, soil analyses must be conducted by a competent person, i.e. a geotechnical engineer, who will determine the adequate support system depending of the nature of the excavation, soil and ground water conditions.

#### **Shoring Systems**

Shoring is the support system designed to prevent the lateral movement of soil to prevent cave-ins. It is commonly used for deep excavations which are five feet or deeper. Various shoring systems are available to prevent excavation cave-ins. Aluminum hydraulic shoring systems have been developed as an economic method to assure the safety of workers. Their light weight and adaptability to varying conditions make them very attractive. Other shoring systems include vertical shores for compact soils ("skip shoring"), stringer systems providing horizontal support for intermittent or solid sheathing for relatively unstable soils, and manhole braces.

#### **Shoring Precautions**

Shoring systems must incorporate certain precautionary features to assure the safety of workers. These are:

- . Providing effective means of access and egress, such as securely fixed ladders in trenches that are four feet or deeper;
- . Erection of temporary barriers to guard against falls; and
- . Construction of diversion dikes and ditches to provide drainage of the adjacent area, which will prevent water from entering into a trench.

## **Sloping**

Sloping is a method which involves cutting the side walls of an excavation to form a safe angle for soil stability. This is called the angle of repose, which represents the angle at which the soil settles to a natural state with no tendency to further settle to a shallower form. The angle of repose varies with the specific soil conditions; however, it can not exceed 45 percent. Sloping is not a practical approach for deep excavations because it requires excessive removal and replacement of soil. However, sloping can be effectively used in conjunction with shoring. Typically, the top of the trench is sloped in such cases to allow for easy installation of the shoring system at lower depths.

## **Trench Shields**

Trench shields (boxes) are essentially used as "personnel protectors". Such devices are commonly placed in an already excavated, but unshored, trench or pit. Normally, the trench walls remain intact long enough to complete the construction. If they collapse, however, a properly designed shield must be capable of withstanding the maximum anticipated lateral soil stress at a given depth. This minimizes the potential for worker injury. Trench shields are most often used in open areas away from existing utilities, streets, and buildings that may require a support system. If ground conditions are favorable and the trench zone requires no direct support, the use of a trench shield may be an excellent choice. However, when the job calls for strict compaction and replacement requirements, one must be cautious. If unstable soils slough off as the shield is pulled up the trench line, it could make proper construction a difficult and costly task (27).

## **Inspections**

Inspection of excavations by a competent person can assist in assessing the soil stability and the quality of the shoring system. Daily inspections should be performed. Attention should be directed to the following during the inspections:

- . Bulges on trench walls, cracks near the edges and walls.
- . Accumulation of loose rocks fallen from the trench wall;
- . Water in the excavation area;
- . Soundness and quality of the shoring materials; e.g. decayed timber; and
- . Improper connections in the shoring system, and other signs of distress;

## **Other Safety Measures**

Other safety measures adopted to protect the workers against excavation hazards are as follows:

- . Keep the excavated soil pile at least two feet from opening to avoid excessive surcharge pressure.
- . Keep all vehicles and equipment away from the trench.
- . Be aware of vibrations, overhead utilities, and underground utilities.
- . Be aware of toxic fumes; toxic fumes can seep through the soil and accumulate at the bottom of an excavation. Clean air should be provided in sufficient volume to dissipate the toxic gases.
- . While excavating the soil, clear all unnecessary workers from the area.

- . Protect the public by installing guardrails, barricades and warning signs around the excavation area.

## APPLICABLE OSHA STANDARDS

OSHA standards for excavations, trenching, and shoring are covered by in CFR 1926 Subpart P, which is presented in Table V-13.

**Table V-13**

### 29 CFR 1926 Subpart P-Excavations, Trenching, and Shoring

<u>Section</u>	<u>Topics</u>
1926.630	Scope, application, and definitions applicable to this subpart
1926.651	General protection requirements
1926.652	Requirements for protective systems

## CONFINED SPACE ENTRY

Confined spaces are enclosed areas having limited access or egress (7). They can be storage tanks, boilers, bins, silos, etc. which are accessible through a manhole. Confined spaces commonly encountered on construction projects include basements, trenches, shafts, bore holes, ducts, pipelines, drains and sewers. Entry into confined spaces can be hazardous and requires special care. Fatal accidents in confined spaces are common.

### Confined Space Hazards

The atmosphere in confined spaces may be hazardous due to lack of oxygen, presence of toxic agents, or presence of flammable and explosive gases. Other hazards in confined spaces include moving parts of machines, extreme temperatures, collapses and cave-ins, and sudden flooding. Difficulty of access and egress, and difficulty of moving in confined spaces amplify the impact of these hazards. Some specific hazards are discussed below.

### Oxygen Deficiency

Small drops in oxygen level can cause loss of balance and concentration, breathing difficulties, and fatigue; and continued drop of oxygen level may result in unconsciousness and death by suffocation. According to NIOSH (28), an oxygen-deficient atmosphere has less than 19.5% available oxygen ( $O_2$ ), requiring an approved self-contained breathing apparatus (SCBA). Atmospheres with less than 16%  $O_2$  cause faulty judgement and rapid fatigue. Atmospheres below a 6%  $O_2$  level create breathing difficulties and cause death in minutes. Oxygen deficiency is most commonly caused by gas leakage into the confined space, oxidation due to corrosion or bacterial growth, and exhaustion of the oxygen supply due to inhalation and combustion.

### Other Atmospheric Hazards

Presence of toxic gases in sufficient quantities is another source of hazard. Hydrogen sulfide is a toxic gas commonly produced by the decomposition of organic matter and is often present in the sewer

systems. Hydrogen sulfide is both toxic and explosive. Another highly explosive gas, methane, is also often present in sewer lines. Other lethal gases are carbon dioxide which is naturally present in soil, and carbon monoxide which is usually produced by internal combustion engines. Leakage can cause chemical vapors to poison a confined space atmosphere; ammonia and chlorine are typical toxic fumes that may be encountered. Nitrous fumes may be left in a confined space immediately after explosive operations. Very small quantities of certain vapors and gases can cause fire and explosions. While methane and hydrogen sulfide are explosive gases, petroleum and vapors of solvents such as acetone and toluene can cause fire.

### **Hazard Control In Confined Spaces**

Good advance planning and adequate training in safe methods of work in confined spaces will enable workers to enter these areas safely. Training will vary according to the nature of the activity and the confined space. The training program should consider the role of supervisors, workers, persons outside the confined spaces, and rescue personnel. A permit-to-work system, in which each step is planned and authorized, is required for confined space entry. Other alternatives to entry should be considered for confined space operations wherever possible. If entry to the space is unavoidable, then appropriate breathing apparatus should be considered. The use of mechanical or forced ventilation is the first choice. Before entry into a confined space, the space should be withdrawn from service and be isolated from electrical and mechanical sources.

### **Monitoring, Protective Equipment and Communications**

Personnel planning to work in confined spaces should check for leakages and test the atmosphere for oxygen, and flammable, explosive and toxic gases. Once begun, the operation should be constantly monitored. Personal protective equipment such as breathing apparatus, harnesses, lifelines, and rescue equipment must be provided and used as necessary. Personnel must be informed on the details of activities and the required communications. A trained person should be in attendance and in continual verbal communication with the workers in confined spaces throughout the operation.

### **Rescue Operations**

Rescue operations may be needed when a person is injured, or collapses in a confined space, becoming unconscious. Rescuers must wear breathing apparatus and safety harnesses that are attached to a lifeline before entering the space. The rescue equipment must include lifting tools such as tripods and winches to carry the unconscious workers.

### **APPLICABLE OSHA STANDARDS**

OSHA has recently issued its final general industry rule for Permit-Required Confined Spaces (29 CFR 1910.146). The standard does not apply to the construction industry; however, contractors are required to protect their employees from confined space hazards. In addition, OSHA's Construction Industry Safety Training and Education Standard (29 CFR 1926.21, paragraphs 6(i) and 6(ii) ) requires construction employers to protect their employees from confined space hazards.

## **CONTAMINATED SITE CLEANUP**

Some construction projects may be planned for sites that are contaminated. Contamination is generally caused by domestic or industrial waste, or from the production and storage of hazardous substances. Soil contamination is most likely to be encountered on sites such as production and storage sites for materials like asbestos, chemicals, explosives, petroleum, metal smelting, paint, steel, etc. Other sites that may be contaminated include dockyards, landfills, mines, quarries, scrap yards and sewage treatment sites. In recent years, public awareness of environmental problems has generated much debate on this issue. Consequently, governments at all levels have enacted legislation requiring the cleanup of contaminated sites, which include provisions for the protection of the personnel employed on these operations.

### **Health and Safety Hazards**

Contaminated sites pose a number of health and safety hazards, which could cause injuries and illnesses. Several factors distinguish the hazardous waste site environment from other occupational situations involving hazardous substances. An important factor is the uncontrollable conditions at the site. In addition, the location and extent of contamination is not always known, and boring and sampling may not properly identify the entire problem. It is also important to recognize that contaminants are subject to relocation with the movement of the ground water.

### **Site Conditions**

### **Hazardous Chemicals**

A large variety and number of substances may be present in a given site. Any individual location may contain hundreds of chemicals, which can present hazards to human and public health. Frequently, an accurate assessment of all chemical hazards is impossible due to the large number of substances present and the potential interactions among the substances. In addition, the identity of the substances is frequently unknown, particularly in the initial stage of a site investigation. Most of the sites contain substances that may be in gaseous, liquid or solid form. These substances may enter the body by inhalation, skin absorption, ingestion, or through a puncture wound. A contaminant can cause damage at the point of contact, or can act systematically causing a toxic effect at a part of the body distant from the initial point of contact. Depending on the toxic material and the duration and magnitude of exposure, adverse physiological reactions such as asphyxiation, irritation, allergic sensitization and other chronic illnesses can be experienced.

### **Biological and Radioactive Hazards**

Besides the chemical hazards, site contamination may be caused by biological agents or radioactive materials. Biological agents are transmitted to the human body by living organisms such as bacteria, fungi, and viruses. Radioactive materials emit harmful radiation in the form of alpha and beta particles and gamma waves. They possess no warning signs such as odor, taste and irritation that would alert the workers to the imminent danger. Radioactive materials commonly pose

long term health hazards.

## **Fire and Explosions**

Many potential hazards for fire and explosions are also present at a hazardous waste site. These include chemical reactions, ignition of explosive or flammable chemicals, ignition of material due to oxygen enrichment, agitation of shock -or friction- sensitive compounds, and sudden release of materials under pressure. Explosions and fires may arise spontaneously. However, more commonly they result from site activities, such as moving drums, accidentally mixing incompatible chemicals, or introducing an ignition source into an explosive or flammable environment. Explosions pose the obvious hazards of intense heat, open flame, smoke inhalation, and flying objects, as well as causing the release of toxic chemicals into the environment.

## **Physical Hazards**

Finally, workers are subject not only to the hazards of direct exposure, but also to the danger posed by the disorderly physical environment of hazardous waste sites, and the stress of working in protective clothing. Trips and falls, striking objects and construction equipment and motor vehicle mishaps are the types of accidents involving physical hazards which can injure workers. Site personnel should constantly look for potential hazards, and should immediately inform their supervisors of any new hazards they note, so mitigative action can be taken.

## **Hazard Control**

OSHA has developed a ten step program to address the health and safety concerns of employees involved in contaminated site cleanup (29). These steps encompass:

- 1) Planning and organization;
- 2) Training;
- 3) Medical programs;
- 4) Site characterization;
- 5) Air monitoring;
- 6) Personal protective equipment;
- 7) Site control;
- 8) Decontamination;
- 9) Handling drums and other containers; and
- 10) Site emergencies.

## **Planning and Organization**

Adequate planning is the first and the most critical element of hazardous waste site activities. The four aspects of planning are:

- 1) Developing an overall organizational structure for site operations to identify the personnel needed, establishing the chain of command, and specifying the overall responsibilities of each employee;
- 2) Establishing a comprehensive work plan that considers each specific phase of the operation;
- 3) Developing and implementing a site safety and health plan, which should determine the health and safety concerns for each phase of the operation and define the requirements and procedures for worker and public protection; and

#### 4) Coordinating with the existing response community.

Planning should be viewed as an ongoing process: the cleanup activities and site safety plan must be continuously adapted to new site conditions, and new information that becomes available.

### **Training**

Anyone who enters a hazardous waste site must recognize and understand the potential hazards to health and safety associated with the cleanup of that site. Personnel actively involved in cleanup must be thoroughly familiar with programs and procedures contained in the site safety plan and must be trained to work safely in contaminated areas. Furthermore, visitors to a site must receive adequate training on hazard recognition and on the site's standard operating procedures to enable them to conduct their visit safely. The objectives of these training programs for employees involved in hazardous waste site activities are:

- . To make workers aware of the potential hazards they may encounter;
- . To provide the knowledge and skills necessary to perform the work with minimal risk to worker health and safety;
- . To make workers aware of the purpose and limitations of safety equipment; and
- . To assure that workers can safely avoid or escape from emergencies.

Employees should not engage in field activities until they have been trained to a level consistent with their job function and the degree of anticipated hazards. The training program should involve both classroom instruction on relevant topics and hands-on practice. A record of training should be maintained in each employee's personnel file to confirm that every person assigned to a task has had adequate training, and that the training is up-to-date.

### **Medical Program**

A medical program is essential to assess and monitor worker's health and fitness both prior to employment and during the course of work, and to provide emergency and other treatment as needed. The medical program should be developed for each site based on the specific needs, location, and potential exposures of employees at the site. The program should be designed by an experienced occupational health physician or other qualified occupational health consultant in conjunction with the site safety officer. A site medical program should provide: surveillance, such as pre-employment screening; periodic medical examinations (case-by-case basis); record keeping; and program review.

### **Site Characterization**

Site characterization provides the information needed to identify hazards and to select worker protection methods. The more accurate, detailed, and comprehensive the information available about a site, the better the protective measures can be tailored to the actual hazards that workers may encounter. The person with primary responsibility for site characterization and assessment is the project team leader. Site characterization generally proceeds in three phases:

- 1) **Off-site characterization** to gather information (before entry) on site location, geological, meteorological and hydrological data, and information on site history regarding presence of hazardous materials;
- 2) **On-site survey** to verify and supplement information from the off-site characterization; and
- 3) **Monitoring** to keep up with changes in site conditions (e.g. atmospheric hazards).

#### **Air Monitoring**

Air monitoring is the process of identification and quantification of airborne contaminant. It can be achieved by direct reading instruments, or by laboratory analysis of air samples obtained from the site. The results from air monitoring indicate the potential inhalation exposure of workers, and determine the extent of hazard and the required control measures.

#### **Personal Protective Gear**

The purpose of personal protective equipment (PPE) and protective clothing is to shield or isolate individuals from chemical, physical, and biologic hazards that may be encountered at hazardous waste sites. Careful selection and use of adequate personal protective gear should protect the respiratory system, skin, eyes, face, hands, feet, head, body and hearing. No single combination of protective equipment and clothing is capable of protecting against all hazards. Thus PPE should be used in conjunction with other protective methods. The use of PPE can itself create significant worker hazards, such as heat stress, physical and psychological stress, and impaired vision, mobility and communication. In general, the greater the level of PPE use, the greater are the associated risks.

#### **Respirators**

Respiratory protection is of primary importance since inhalation is one of the major routes of exposure to chemical toxicants. The federal regulations require the use of respirators that have been tested and approved by the Mine Safety and Health Administration (MSHA) and the National Institute of Occupational Safety and Health (NIOSH). Relevant testing procedures are described in 30 CFR Part 11.

#### **Protective Clothing**

Personal protective clothing is considered to be any article offering skin or body protection. It includes fully-encapsulating suits, non-encapsulating suits, aprons, leggings, and sleeve protectors, gloves, firefighter protective clothing, proximity garments, blast and fragmentation suits, cooling garments, and radiation-protective suits. Special protective clothing is available offering a range of protection against different chemicals. Selection of protective clothing is a complex task and should be performed by personnel with training and experience based upon factors such as permeability, durability, flexibility, temperature effects, ease of decontamination, compatibility with other equipment, and duration of use.

#### **Site Control**

Several site control procedures can be implemented to reduce worker and public exposure to existing hazards. These encompass:

- . Making a site map;
- . Site preparation for subsequent activities;
- . Establishing work zones;
- . Using the "buddy system" when necessary;
- . Establishing site security measures;
- . Setting up communication networks; and
- . Enforcing safe work practices.

## **Work Zones**

The work zone concept deserves special mention. To reduce the accidental spread of hazardous substances by workers from the contaminated area to the clean area, zones should be delineated on the site where different types of operations will occur, and the flow of personnel among the zones should be controlled. The establishment of work zones will help ensure that the personnel are properly protected against the hazards, work activities and contamination are confined to the appropriate areas, and personnel can be located and evacuated in an emergency situation. Hazardous waste sites should be divided into as many different zones as needed to meet operational and safety objectives. The three frequently used zones are:

- 1) **Exclusion Zone**, the contaminated area;
- 2) **Contamination Reduction Zone (CRZ)**, the area where decontamination takes place; and
- 3) **Support Zone**, the uncontaminated area where workers should not be exposed to hazardous conditions.

Delineation of these three zones should be based on sampling and monitoring results and on an evaluation of potential routes, and the amount of contaminant dispersion in the event of a release.

## **Decontamination**

Decontamination is the process of removing or neutralizing contaminants that have accumulated on personnel and equipment. It is critical to health and safety at hazardous waste sites because it protects workers from hazardous substances that may contaminate and eventually permeate the protective clothing, respiratory equipment, tools, vehicles, etc. Decontamination protects all site personnel by minimizing the transfer of harmful materials into clean areas, and protects the community by preventing uncontrolled transportation of contaminants from the site. Therefore, a decontamination plan should be developed (as part of the site safety plan) and set up before any personnel or equipment may enter areas where the potential for exposure to hazardous substances exists. The decontamination plan should:

- . determine the number and layout of decontamination stations;
- . determine the decontamination equipment needed;
- . determine the appropriate decontamination methods; and
- . establish procedures to minimize worker contact with contaminants during removal of personal protective clothing and equipment.

## **Handling Drums and Other Containers**

Accidents may occur during handling of drums and other hazardous waste containers. Hazards include detonations, fires, explosions, vapour generation, and physical injury resulting from moving heavy containers by hand and working around stacked drums, heavy equipment, and deteriorated drums. While these hazards are always present, proper work practices such as minimizing handling and using equipment and procedures that isolate workers from hazardous substances can minimize the risk of site personnel. The appropriate procedures for handling drums depend on their type, contents, and condition. Thus, prior to any handling, drums should be visually inspected to gain as much information as possible on these aspects. The inspector should look for:

- . Symbols, words, or other marks on the drum indicating that its contents are hazardous, e.g., radioactive, explosive, corrosive, toxic, flammable;
- . Signs of deterioration such as corrosion, rust, leaks, or bulging due to internal pressure; and
- . Drum type, and the drum head configuration.

## **Monitoring**

Monitoring should be conducted around the drums using instruments such as a gamma radiation monitor, organic vapour monitor, and a combustible gas meter. If buried drums are suspected, ground-penetrating systems, such as electromagnetic wave, electrical resistivity, ground-penetrating radar, magnetometry, and metal detection devices can be used to estimate their location and depth.

## **Site Emergencies**

Site emergencies is the final category that must be considered during an effective cleanup operation of hazardous waste. Emergencies happen quickly and unexpectedly and require immediate response. Site emergencies can present complexities. Uncontrolled toxic chemicals may be numerous and unidentified; their effects may be synergistic. Hazards may potentiate one another; for example, a flammable spill may feed a fire. Rescue personnel attempting to remove injured workers may themselves become victims. This variability means that advance planning, including anticipation of different emergency scenarios and thorough preparation for contingencies, is essential to protect worker and community health and safety. Therefore, a contingency plan is required as a discrete section of the site safety plan.

## **Contingency Plan**

The contingency plan sets forth policies and procedures for responding to site emergencies, and should incorporate:

- . The roles, lines of authority, training, and communication of personnel.
- . Mapping, security and control, refuges, evacuation routes, and decontamination stations at the site;
- . Medical/first aid;
- . Equipment;
- . Emergency procedures
- . Documentation; and
- . Reporting.

The contingency plan should be compatible and integrated with the pollution response, disaster, fire, and emergency plans of local, state,

## APPLICABLE OSHA STANDARDS

and federal agencies. The plan should be rehearsed regularly using drills and mock situations and be revised periodically in response to new or changing site conditions or information.

OSHA standards applicable to contaminated and hazardous waste sites are summarized in Table V-14.

**Table V-14**  
**OSHA Safety Standards Applicable to Work on Contaminated and Hazardous Waste Sites**

Safety Topics	29 CFR 1910	29 CFR 1910
Ventilation	Subpart G 1910.94	Subpart D 1926.57
Noise	Subpart G 1910.95	Subpart D 1926.52
Ionizing Rad.	Subpart G 1910.96	Subpart D 1926.53
Hazardous Mat.	Subpart H	
PPE		
General	Subpart I 1910.132	
Eye / Face	Subpart I 1910.133	Subpart E 1926.102
Hearing	Subpart I 1910.95	Subpart E 1926.101
Respiratory	Subpart I 1910.134	Subpart E 1926.103
Head	Subpart I 1910.135	Subpart E 1926.100
Foot	Subpart I 1910.136	
Fire Protection	Subpart L	Subpart F
Material Handling & Storage	Subpart N	Subpart H
Electrical	Subpart S	Subpart K
Toxic / Hazardous Substances	Subpart Z	
Trenching & Excavation		Subpart P

## REVIEW QUESTIONS

1. What types of industry and government resources and standards are available on construction safety and health?
2. What types of activities does the term material handling encompass, as covered in this module?
3. What are the different ways hazardous materials are classified?
4. How can hazardous chemicals enter the human body? How do they affect it?
5. List the various federal laws governing the control of hazardous materials for public and occupational safety and health. What are their aims and coverage?
6. Describe the right-to-know laws and the Hazard Communication Standard. What is the role of MSDS in their implementation?
7. Discuss the material handling hazards related to delivery, storage and movement. What are the means of effectively controlling these

hazards?

8. What are the best practices for housekeeping?
9. Discuss the general and specific rules for safe manual lifting.
10. Describe the NIOSH equation for manual lifting. What is the significance of the lifting index (LI)?
11. What are some of the tools and equipment used to assist in the manual handling of materials?
12. Summarize the safe rigging procedures.
13. What are the differences between gas, arc, and resistance welding (and cutting)?
14. Name the principal hazards associated with welding and cutting. How can they be controlled and prevented?
15. What are the three main categories of concrete hazards?
16. Discuss the concrete material hazards and their control.
17. Describe the formwork and shoring hazards associated with concrete construction, along with the necessary measures for their control.
18. What types of hazards arise during rebar and concrete placement? How can these tasks be performed safely?
19. Name the precautions necessary for cold weather concreting.
20. Discuss the hazards and precautions associated with steel erection operations.
21. What are the typical construction activities exposing workers to fall hazards?
22. Distinguish between fall prevention and fall protection; between active and passive fall protection.
23. Discuss ladder hazards and safety, and scaffolding hazards and safety.
24. Describe the hazards and safety measures associated with open sides and floor openings, and associated with roofing work.
25. What is meant by a motion-stopping safety system?
26. Discuss the hazards and safety precautions associated with cranes, derricks, and hoists?

27. What are the principal safety hazards of operating heavy construction equipment such as bulldozers, scrapers, graders and loaders? How can these hazards be prevented or mitigated?
28. Describe the safety hazards and precautions related to motor vehicles in the construction project environment.
29. List the hazards of using manual tools, electric tools, saws, and powder actuated tools. Discuss the relevant hazard control principles and practices.
30. What types of safety hazards are associated with electrical work? How can these hazards be controlled?
31. How are injuries and fatalities caused by electricity?
32. What are the factors contributing to cave-ins during excavation and trenching operations?
33. Name some excavation and trenching hazards other than cave-ins.
34. Discuss hazard control in excavation and trenching addressing the shoring systems, sloping, and trench shields.
35. Define the term confined space. What types of hazards are present in confined spaces? Describe the hazard control principles associated with confined space entry.
36. List the health and safety hazards which must be considered in hazardous waste site cleanup work.
37. Describe OSHA's ten step program designed to address the health and safety concerns of employees involved in contaminated site cleanup operations.
38. Name the OSHA standards (by part, subpart and section number) applicable to the various construction operations, activities and tasks covered in this unit.

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**UNIT VI**  
**ENGINEERING, DESIGN AND CONTRACT ADMINISTRATION**  
**FOR SAFE CONSTRUCTION**

**PURPOSE**

To present information on the engineering, design and contract administration factors affecting the structural safety of constructed facilities.

**OBJECTIVES**

To educate civil engineering students through case histories on the principles and concepts of:

1. The causal factors of construction failures, including
  - (a) Natural disasters
  - (b) Engineering and design considerations
  - (c) Material properties and performance
  - (d) Construction methods and procedures
  - (e) Contract administration and project management
2. Safety implications of the constructability concepts, shop drawings and change orders
3. Temporary structures
4. Engineer's role regarding safety and quality assurance
5. Liability issues for engineers.

**KEY TERMS**

Construction failure; structural failure; design deficiency; structural details; erection procedures; communication process; natural disasters; constructability; job hazard analysis; material properties; environmental effects; contract administration; shop drawings; change orders; design engineer; field inspection; quality control; construction loads; temporary structures; professional liability; standard of care; expert witness; doctrine of privity; strict liability.

**UNIT VI**  
**ENGINEERING, DESIGN AND CONTRACT ADMINISTRATION**  
**FOR SAFE CONSTRUCTION**

**CONSTRUCTION  
FAILURES**

Tragic construction failures, especially those which involve fatalities and substantial economic losses, often receive wide media coverage and bring public outcry for preventive actions. Such incidences have frequently led to federal investigations, and controversy and debate within the civil engineering and construction community, and have prompted legislative initiatives. The following are a few of the most infamous examples of construction failures, which have caused great losses and generated significant public and professional interest.

**L'Ambiance Plaza  
Condominium  
Collapse**

On April 23, 1987, L'Ambiance Plaza, a 16 story apartment building in Bridgeport, Connecticut, collapsed during construction. The lift slab method was being used in this project to erect the structure. The collapse resulted in 28 fatalities and 18 injuries, which made L'Ambiance the most catastrophic construction accident of the 1980's. An investigation was performed by the National Bureau of Standards (NBS; now called NIST - the National Institute for Standards and Technology) to determine the most probable cause of this collapse. This investigation (1) concluded that the most probable technical cause of the collapse was the failure of some lifting assembly components, designed and erected by the lift slab contractor and its subcontractor.

*Subsequent  
Forensic  
Investigations*

Several subsequent forensic investigations were also conducted on this accident identifying design deficiencies and suggesting various alternative failure mechanisms (2,3,4). Many experts involved in this work believe that the fragmentation of responsibility, the delegation of structural design to the contractors, and poor communication between the parties were the underlying reasons that led to the collapse of L' Ambiance Plaza (5).

**Willow Island  
Cooling Tower  
Collapse**

In April 1978, the hyperbolic cooling tower of the Pleasants Power Station near Willow Island, West Virginia, partially collapsed during construction, resulting in the death of 51 construction workers. The patented jumpform scaffolding, which was supported by the partially completed concrete shell, collapsed as the connecting anchors pulled out of the partially matured concrete, one day after the pouring (6). This accident brought to the nation's attention the potential hazards of temporary structures and the potential limitations of construction materials.

**Kansas City  
Hyatt Regency  
Walkway Collapse**

Although this failure did not occur during construction, an important lesson may be learned from the errors which led to it. On July 17, 1981, the second and fourth floor hanging walkways spanning across the atrium of the Hyatt Regency Hotel in Kansas City, Missouri, collapsed and fell to the ground floor during a social event. Described as "the most devastating structural collapse ever to take place in the United

States" (7), this failure took the lives of 114 people and injured 200 more. According to NBS, which performed an investigation on the failure, the cause of the collapse was inadequate connection details between the steel box beams and the hanging rods (7,8).

### *Structural Details*

It was found that without the consent of the engineer of record, these critical details were altered by the steel fabricators in such a way that the main source of support for the second floor walkway was transferred from the roof to the fourth floor walkway, creating an overload situation. This flawed revision was not noticed by the engineer of record, who checked the shop drawings only for conformance to the original design. This failure raised the question of responsibility for the shop drawings and the design of structural details, causing the engineering profession to start reconsidering the traditional practices with regard to structural details, particularly those which do not conform to the American Institute for Steel Construction (AISC) standards.

### **CAUSES OF CONSTRUCTION FAILURES**

Prevention of construction failures, first and foremost, require the understanding of the causes. Many efforts have been directed toward this end by engineers, forensic scientists, the legal community, and legislators (9,10). In the early 1980's, this problem was addressed by the Investigations Subcommittee of the House Committee on Science and Technology through a study aimed at determining the underlying causes of the construction failures, and the possible related shortcomings in technology and education. This investigation was based on extensive interviews with construction engineers focusing on the understanding of the actions that take place during construction. The findings of this study were summarized as follows (11):

### **Findings of the House Committee on Science and Technology**

- . The organization of a construction project is unique since it brings together many parties for a limited period of time.
- . There is little evidence of the presence of consistent methods of maintaining overall project quality.
- . The structural engineer in charge of design does not perform all of the design work; important details are implemented by steel fabricators.
- . The structural engineer, who is the logical person to inspect a structure, is discouraged from doing so.
- . Recent engineering graduates are well trained in mathematics and computers, but are relatively unsophisticated about the behavior of structures.
- . Long-span structures require careful quality control, and there is a need for new approaches emphasizing dynamic behavior analysis.

### **Recent Research Findings**

More recently, Eldukair and Ayyub (12) conducted a comprehensive study of the causes of construction/ structural failures, by reviewing 604 cases which occurred in the United States between 1975 and 1986. They discovered that:

- . Nearly 57 percent of failures resulted in collapse and 4 percent

resulted in other unsafe conditions.

- . A critical percentage (43.7 percent) of the structural failures occurred during the construction phase.
- . Errors in design and construction phases of the projects were the most predominant sources of failures. Design errors occurred in 51 percent of the total failure cases; 57 percent of the total failure cases recorded deficiencies in construction procedures.
- . Structural designers were responsible for the errors in 48 percent of the cases. Contractor's site staff was accountable for errors in 60 percent of the total failure cases.
- . Deficiencies in the construction procedures primarily involved inadequate construction methods, ineffective evaluation of laws and safety regulations, and inadequate planning and supervision.
- . Errors in management practices had a tremendous effect on the performance of project activities, the schedule, and safety. These included deficiencies in work responsibilities, deficiencies in the communication process, and insufficient work cooperation. Errors in defining work responsibilities were dominant (30%) as part of the deficiencies in management practices.
- . A great majority of the cases (86%) indicated that reinforced concrete elements were involved in the failures, and the highest number of failed members (34%) were slabs and plates.
- . The primary causes of most failures were poor erection procedures and inadequate connection elements leading to inadequate load behavior, followed by unclear contract information, and contravention of information. A small percentage of failures were attributed to unforeseen events.
- . Secondary causes of failures were led by environmental effects (mostly poor weather conditions), followed by poor supervision and control, poor communications, poor material and equipment usage, poor workmanship, and other minor technical and nontechnical factors.

#### *Toll of Failures*

The study found that the cases examined caused 416 total deaths and 2515 total injuries. The total direct costs of damage associated with the studied structural and construction failures in 1986 were estimated at \$3.5 billion. The hidden indirect costs were excluded from the estimate because of the difficulty of their determination.

#### *Need for Inspection and Control*

It was also observed in the study that errors can be discovered with additional inspection procedures along the planning, design, construction and utilization phases of the building process. The authors recognized four areas of control to prevent failures:

- . Appointment of experienced and qualified site staff;
- . Implementation of quality assurance and quality control procedures;
- . Enforcement of penalties on contractors; and
- . Implementing systematic procedures; i.e. planning, scheduling, supervision and control.

**Classification  
of Causal Factors**

These studies and others have shed considerable light on some of the common causes of construction failures. Based on these considerations, it is possible to summarize the causal factors governing construction failures into 5 major classifications, which are:

- 1) Natural disasters;
- 2) Engineering and design considerations;
- 3) Material properties and performance;
- 4) Construction methods and procedures; and
- 5) Contract administration and project management.

**Natural  
Disasters**

Natural phenomena such as earthquakes, hurricanes, violent storms, tornados, etc. often cause enormous destruction to buildings and other structures during construction or service, leading to loss of life and property damage of significant magnitude. Although most structures can be designed and constructed to withstand such overwhelming forces of nature, some damage is often unavoidable (hence the term "Act of God"). However, a natural disaster may also reveal a latent deficiency in design, construction techniques, or code requirements.

**Hurricane Andrew**

A recent example (1992) is Hurricane Andrew, which resulted in the costliest disaster in U.S. history. This violent storm with gusty winds exceeding 150 mph, devastated many buildings, while revealing critical deficiencies in construction practices in the South Florida area. This fact became particularly evident in residential construction, where roof failures caused by inadequate connections (13) resulted in the total destruction of many wooden frame houses. Experts pointed to cost cutting measures by contractors as a contributing factor for the great damage caused by Hurricane Andrew.

**Concerns for  
Public Safety**

Such disasters may expose critical deficiencies in structures, raising concerns for public safety. The engineering community should recognize the threat of natural disasters in geographic areas susceptible to them, and propose corrective measures through code revisions to eliminate or mitigate the potential failures.

**Engineering and  
Design**

Engineering and design for construction involve complex processes, which blend technical expertise with skillful project organization and management. In addition to design and construction knowledge, an understanding of government regulations and building codes are necessary, along with effective communications with various groups involved in the construction process.

**Constructability**

An important prerequisite to safe design and engineering is the consideration of constructability. The constructability task force of the Construction Industry Institute (CII), has defined constructability as the optimum integration of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall

project objectives (14). It is indicated that this approach will lead to greater productivity, lower costs, and improved quality and safety.

### *Design Aspects*

According to CII, the design process must integrate construction needs from the conceptual stage to final delivery of contract documents. Constructability analysis of the design can identify conflicts and shortcomings that may complicate construction. It is therefore beneficial to integrate such an analysis into the project execution plans starting with the preliminary design stage. Meaningful input from the constructors, construction managers or constructability consultants can be very beneficial in the early stages of a project. Several critical decisions are made during the schematic design stage that will determine many subsequent construction activities. Factors such as availability of raw materials and skilled labor, costs, and the overall project schedule can be incorporated into these decisions. It might be assumed that the project schedule is construction sensitive, and the general construction methods might consider the impact of seasonal weather conditions, site characteristics, drainage and soil conditions.

### *Constructability Reviews*

Constructability reviews can be applied in more depth during the design development and construction document preparation phases by incorporating the following objectives and principles (14):

- . Design configurations should enable efficient construction and eliminate spatial constraints, which complicate proper assembly, especially for large structural elements.
- . Sequence of design should follow construction logic and take into account feasible construction time. For example, it may be important to realize certain slabs which are designed for service loads may not support the construction loads.
- . Complicated construction details should be minimized, especially if they require extensive on-site assembly. Standardization and pre-assembled design should be maximized.
- . Construction task interdependencies that would bring many trades together should be minimized.
- . Flexibility for field adjustments during implementation should be allowed, and tight tolerances should be eliminated. An example of this would be certain structural members which have adequate depth to support the service loads not allowing for the necessary connections.
- . The site layout should consider accessibility, and in contract documents there should be provisions for safe access for workers and storage materials and equipment.
- . The construction team should provide input and advice on access needs, major equipment placement, and storage requirements.
- . Potential conflicts between underground work and heavy equipment movement should be eliminated.
- . The design and erection sequence should consider the stability of incomplete structural frames during construction.

- . If the project needs to be completed during adverse weather conditions, design procurement should facilitate an early enclosure of the structure to minimize the exposure to harsh weather. Specifications should promote the use of weather compatible materials, and limit field work by using preassembled modules.

#### *Impact on Safety*

These principles imply that the consideration of constructability issues during design can eliminate difficulties in execution of construction tasks and avoid unsafe conditions on the job site. Engineers and architects can address safety issues by using a method known as "job hazard analysis" during the initial planning and design stages. This technique can assist in identifying accident producing conditions and their locations and providing the corrective measures to eliminate hazards. Finally, all document conflicts and discrepancies of information caused by the possible lack of coordination between different sections of the construction documents should be eliminated. Such conflicts and gaps may go unnoticed and create constructability problems (such as incompatibilities between structural members and mechanical elements) when the project has reached an advanced stage.

#### **Material Failures**

Many structural/construction failures are caused by material deficiencies. Materials, in and of themselves, may not be defective; however, their inappropriate selection or utilization in the construction process may lead to failures. Understanding the nature and properties of the materials, along with their structural behavior, and strength and durability performance in the service environment, is vital to the successful performance of the structure, and the avoidance of failures. For instance, freeze-thaw effects and shrinkage problems in concrete are well known. However, strength development (maturity) is somewhat less understood. The collapse of the Willow Island cooling tower mentioned earlier was primarily attributable to incomplete curing of the concrete resulting in insufficient material strength at the time of formwork removal.

#### *Potential Limitations of Materials*

Building products have been continually evolving and their changing attributes may present a challenge to the designers. New materials, as well as technological advancements in traditional materials, create the possibility of not fully understanding their potential limitations. For instance, the performance of plastics which are gaining acceptance in the construction industry have not been fully tested for all service conditions. Improved properties of steel, concrete and wood can enhance structural performance, but may also present some problems. For instance, higher strength steel facilitates greater space availability, but it may offer reduced ductility.

#### *Effects of Environmental Conditions*

The effects of environmental conditions on materials is also an important concern. For example, metals under certain conditions, are subject to corrosion, despite conventionally adequate safeguards and quality

control. Galvanic action between certain metals is a common cause of corrosion. Metal fatigue may create cracks which weaken the material, and facilitate chemical reactions promoting corrosion. Contrary to common belief, concrete does not always provide adequate protection to reinforcing steel. Moisture can reach the steel through the cracks (and sometimes pores) in concrete causing corrosion, which can lead to total deterioration. Chlorides also promote corrosion in steel. They can come from deicing salts, or from chloride additives used in high-bond mortar (10).

### *Incompatibility of Materials*

Incompatibility of materials which come in contact in the constructed form may also cause deterioration. Different materials which form the composite members of a structural member may have incompatible tolerances, strengths and ductilities. These differences can produce unanticipated stress redistributions. Incompatibility may also lead to differential movements resulting from temperature and moisture gradients. Different materials have varying coefficients of expansion. For instance, brick, limestone and concrete have uniquely different coefficients, and under the same temperature gradient, they may expand and contract at different rates leading to cracks.

### *Material Selection*

Some of the most important decisions regarding design, and constructability reviews involve material selection. Engineers and architects must specify the materials, approve substitutions (as may be required by value engineering analysis), and test the quality of the material during construction. These tasks must take into account all exposures, compatibility, and the limits of performance. In the selection of materials, manufacturer's design and performance data must be scrutinized, and qualitative information should be clearly documented.

### **Contract Administration**

Contract administration encompasses all activities from the beginning to the end of a construction project relating to the execution of the project tasks as provided for by the contract documents. Shop drawings and change orders are the two most important aspects which may impact construction safety. They are discussed in the following paragraphs.

### **Shop Drawings**

Shop drawings are documents prepared by various subcontractors who will perform specific construction tasks. They usually show the specific components of the constructed system and the details of the erection procedure. Shop drawings have two critical purposes. First, they constitute the contractor's interpretation of the design documents. Secondly, they provide the freedom to contractors (especially in complex projects) to propose construction details. This is particularly necessary where it is not economically feasible to include all the necessary details on the contract documents. It should be noted that, in many cases, suppliers and subcontractors may have greater expertise in materials, construction methods, and familiarity with some new

technologies, than the designer. This freedom generally results in a competitive bid since the contractor is not forced to comply with specific methods in which he may not be totally proficient. Shop drawings are reviewed by both the contractors and the designers. They are reviewed more critically by the responsible designers if the case concerns structural details. Usually shop drawings receive precedence over contract documents, and thus become the sole source of information and guidance for the construction team. Any errors or omissions on shop drawings can lead to inadequate construction which may result in failures.

#### *Deficiencies in Processing*

Deficiencies in shop drawing submittal and processing practices can jeopardize safe and efficient construction. Three crucial factors must be observed to minimize such problems, namely:

- 1) Efficient planning and time management;
- 2) Adequate shop drawing reviews; and
- 3) Good communication between the designer and the contractor.

#### *Coordination with Schedule*

Shop drawings must be coordinated with the construction schedule, which should be based on critical path considerations. Since the ordering and fabrication of most materials are dependent upon their respective shop drawing reviews, unreasonable delays by contractors and/or designers in completing these tasks may lead to overall project delays, and budget overruns. However, shortage of time, pressures from the contractor, or budgetary concerns must not be compromising factors, jeopardizing safe design and construction. Shop drawings must always be thoroughly reviewed by the members of the design team, who have adequate knowledge of and familiarity with the task, and the design concept.

#### **Effective Communication**

Effective communication is perhaps the most critical factor in preventing failures. In practice, there is often some overlap of design responsibility between the engineer/design professional and the contractor / subcontractor. This is especially common in certain areas like steel connections or precast concrete construction. It is important that the designers develop excellent communications with the contractors, and clearly express their intentions. Also, the contract documents must clearly define the extent of the contractors' responsibilities to eliminate any misunderstandings.

#### **Communication Failures in Hyatt Regency Collapse**

An unfortunate example of communication failure is the collapse of the Hyatt Regency walkways described at the beginning of this unit. In this case, the technical cause of the collapse was found to be the inadequacy of critical steel connections. The original contract documents had called for a set of continuous hanger rods, which would suspend from the roof framing and pass through the fourth floor box-beam on through the second floor. As constructed, however, two sets of hanger rods were used, one set extending from the fourth floor box-beam to the roof framing, and another set from the second floor box-beams to the fourth floor box-beams. It is believed that the fundamental reason which led to inadequate design of details was the failure of the engineers to properly communicate their intentions to the steel fabricators.

According to Bansen and Parsons (8) who studied the problem, there was a critical misunderstanding about individual and overlapping responsibilities which led to serious breaches in communications between the team members. Apparently, the structural engineer failed to clearly communicate specific load information to the steel fabricators, and the engineer of record delegated the design responsibility for the box beam to the fabricator. Due to the omission of this critical information, the fabricator acted upon the wrong assumption that the engineer's connection details were complete, and they merely had to be developed. The commission which investigated this accident on behalf of the state of Missouri ultimately concluded that the burden of communication between the constructor and the designer laid on the latter party.

**Shop Drawing  
Reviews for  
Hyatt Regency**

The Hyatt Regency collapse also generated considerable debate with regard to the inherent dangers of the traditional practices concerning shop drawing reviews. In approving the shop drawings, design engineers generally do not assume responsibility for the accuracy of the work represented in the drawings. They simply verify that the information submitted is in conformance with the design. In fact, the reviewed shop drawings usually contain a statement which defines the limits of the engineer's professional liability in terms of the scope of evaluation and the resulting action expected from the review. On the other hand, some contractors view the engineer's approval as assumption of responsibility for the outcome of the shop drawing. The fact that structural engineers for the Hyatt Regency walkways were found liable, indicates that the engineer's role and responsibility is beyond just reviewing the shop drawings to check for conformance to the design concept.

**ASCE Quality  
Manual**

In the years following this tragedy, ASCE has addressed this issue in its recent quality manual (15). It encourages continuing interactions between design engineers and fabricators and allows delegation of design responsibility to the fabricators, provided that they are performed under the supervision of a qualified (licensed) professional engineer. However, ASCE has also stated that the engineer of record should assume the overall responsibility for design.

**Change Orders**

A change order is essentially a communication tool which is issued by designers to the contractors/subcontractors during the construction phase to alter the course of a project with owner's approval. The necessity for a change order may arise from unexpected site conditions, unavailability of materials or equipment, potential design flaws, changes in owner's requirements and other relevant factors.

*Impact on  
Budget, Schedule  
and Safety*

Change orders may have profound impacts on the project budget and schedule, often imposing additional demands and liability for cost of the related design and construction. This fact, coupled with time constraints and pressures during construction, can cause the designers to pay

insufficient attention to the preparation of change orders. Yet, change orders become a part of the contract documents, and any errors or omissions on them actually can become design flaws, which might have an impact on the safety of the constructed facility and the site personnel. Change orders should contain clearly written instructions supported by complete and accurate drawings to avoid confusion and poor guidance on the project changes.

### **The Role of the Design Engineer**

Many building failures occur during construction. As the most critical phase of a project, construction, especially the erection of the structural frame, warrants special attention from the design engineer. Ironically, the design engineer's role during this phase is decreasing, despite the growing complexities associated with the construction process and technology.

### **Erosion of Authority over Design Execution**

According to Carper (16), there are two basic reasons for the erosion of the engineer's authority over the execution of design. The first reason is the issue of professional liability and some seemingly arbitrary litigation outcomes. In response to this dilemma, many engineers have voluntarily reduced or eliminated the field inspection functions from their services. The increase in legal exposure is arguably a legitimate business concern; however, indemnification has proven to be a weak legal defense. Further, it was observed that the design engineers responsible for the Hyatt Regency Hotel were held liable for the collapse, despite their attempt to relinquish their design responsibilities to the fabricators. Similarly, the design engineer for L'Ambiance Plaza, who did not perform field inspection, surrendered his full professional insurance policy to settle legal claims resulting from the collapse.

### *Legal Exposure*

### *Cost Factor*

The second reason for the loss of engineer's control is the cost. In an attempt to reduce cost, clients are often reluctant to retain the services of the design engineer for field inspection, if they find a less expensive alternative. In a competitive market, engineers may have to agree to this conflict in responsibility and authority, in order to appease clients. Occasionally (especially in fast-track construction projects) the responsibility for field inspection is left to the discretion of the construction manager. Since the desire to reduce the cost and duration of construction is an important consideration to the construction manager, this approach may be preferable; but it may compromise quality and safety.

### **Design Engineer's Role in Construction**

It is clear that, in the interest of safety and quality, the design engineers should assume a greater role during the construction phase of a project in order to control the execution of their design. Engineers can improve the quality of construction by:

- . Assuring that the construction materials meet the specification requirements;
- . Assuring that the construction details conform to the contract

- documents;
- . Evaluating the design performance and checking for errors; and
- . Interpreting the intent of contract documents.

*Role Defined  
in Contracts*

The degree of the engineer's involvement in the construction phase could vary depending on the nature of the project and should be defined in the contractual agreements between the designer and the owner.

**Design Engineers  
as Inspectors**

Recent construction failures have alerted the public to the importance of construction inspection by design engineers. Many governmental agencies at the local and state levels now require some form of inspection by the engineer of record. After the collapse of the L'Ambiance Plaza apartment building, the State of Connecticut enacted legislation which requires the architects/engineers to certify that the completed building is in conformance with their contract documents. Similarly, following the collapse of the Harbor Cay condominium project (not elaborated herein), the State of Florida mandated that certain buildings, especially those with unique design features, should be erected in the presence of a special inspector who must be a professional engineer or a registered architect in the state of Florida (17).

**Quality Assurance  
and Control  
Programs**

The construction phase is by far the most demanding portion of a project. All evidence seems to point to the importance of a well defined and organized field inspection and quality assurance and control program recognizing the roles of the owner, designer and contractor. Reluctance of the design engineer to interfere in construction issues for fear of legal exposure may not be a sound strategy for avoiding liability. Recently, OSHA has linked some construction accidents to inadequate or faulty design decisions and indicated that the design professionals perform "construction related acts" by virtue of their involvement in design, although this claim has been strongly contested (18). Some recent litigation cases have sought to increase the engineer's role in construction methods and safety. For instance, the L'Ambiance legal settlement has shown that design professionals can no longer rely on "observation only" type contractual agreements, and might be subject to costly litigation, should construction problems arise. Therefore, it appears in the professional interest of the engineers to lead quality control programs more aggressively, eliminate poor materials and craftsmanship, and prevent failures for obvious reasons, as well as a means to avoid professional liability.

**Construction  
Methods and  
Procedures**

In present practice, the construction methods and procedures by which a building is erected are considered to be the responsibility of the contractor. In a great majority of construction projects, constructors are proficient and possess sufficient knowledge and experience in their work. However, there may be some construction situations requiring sophisticated structural design decisions at the time of erection, and some constructors may attempt to make such decisions on their own

despite a possible lack of capacity to do so. This may cause problems regarding structural safety.

### **Construction Loads**

One such area is construction loads, which may at times exceed the anticipated service loads. Construction loads were a critical element in the failure of L'Ambiance Plaza, and were not adequately addressed due to the fragmentation of the design process and the misunderstandings regarding responsibility. Apparently, the engineer of record proposed the structural concept, namely the lift slab method, with a post-tensioned concrete slab. However, critical elements such as the design of the lifting equipment, columns and lateral bracing were left to the discretion of the contractors. Some of these factors were blamed for the failure (4,5).

### **Temporary Structures**

Temporary structures cover those structures temporarily erected to assist in the construction operations, and are central to shoring, formwork and slip forms, scaffolding, ramps and platforms, bracing and guying, cofferdams, etc. Contract documents prepared by the engineers may specify the design of the temporary structures, or may require that the contractor develop the necessary temporary structures. In the latter case, the contractor generally assumes responsibility for their integrity.

### ***Scaffold Failures***

Scaffold failure is a common type of accident associated with temporary structures as demonstrated by many case histories. A scaffold resting on concrete blocks collapsed in Chicago killing twelve workers (10). Insufficient strength of the concrete blocks were determined as the cause of collapse. Fourteen injuries were reported on another accident in New Jersey when a scaffold collapsed pulling over a 12 feet high masonry wall to which it was tied (19). Overloading with construction materials, coupled with poor base support of the planks was the apparent cause of failure. In a gymnasium remodeling project in Illinois, the roof collapsed when the scaffold failed to support the roof after the supporting beams were removed (20). The court decided that the designers were at fault in that they did not determine the scaffold's ability to support the roof since the scaffold was intended to be used as a shoring system. These cases underscore the importance of sound design and construction of scaffolds.

### **LIABILITY ISSUES**

Any decision of professional liability must begin with a basic understanding of legal concepts as they apply to engineers. In the American legal tradition the laws are created by the legislative branch, enforced by the executive branch, and interpreted by the judicial branch. Sources of these laws are:

- . Constitutions of both the federal and state governments;
- . Statutes and ordinances passed by federal, state and local legislative bodies;
- . Administration rules and regulations; and
- . Common law (also known as case law) which is a set of legal

principles based on judicial decisions rendered by other courts regarding similar cases. These decisions are respected as laws, and are ordinarily used as precedents, when needed.

### **Liability for Professional Services**

Liability for negligence dates back to the ancient Mesopotamian civilization, where the much noted code of Hammurabi stated (10): "If a builder builds a house for a man and does not make its construction firm, and the house which he has built collapses and causes death of the owner of the house, that builder shall be put to death".

### **Standard of Care**

The English common law, which was adopted in the U.S., holds a person who represents himself with certain abilities and skills in which the public trusts, liable for negligence, if the expected skills and services are breached. In order to prove negligence, the courts have established a concept known as the "standard of care" which is a standard of service by a reasonable and prudent person with ordinary professional competence. This implies that, in carrying out its responsibilities, the A/E is required to possess and exercise the level of skill and judgement that is accepted among similarly situated design professionals (21). This standard may include both actions or lack thereof. The law requires that all professional services be performed with ordinary care and skill; however, it does not require that the results of such services be guaranteed. The judgement regarding standard of care varies according to the circumstances, and is generally drawn from community practice, government standards, industry standards, statutes and regulations, and judicial decisions.

### **Role of Engineer as Expert Witness**

Ordinarily, the standard of care is determined in each case independently based on the state of practice at the time the service was performed. In a legal dispute, opposing parties may present expert witnesses (often engineers) who may testify on the competence of the services as it compares to that of another reasonable/prudent engineer in the same community. Bachner (21) has emphasized that it is the expert's duty to perform the research necessary to establish the facts about the case and be totally impartial, although he/she is paid by a plaintiff or defendant. Thus, when experts disagree about given issues, as commonly is the case, the disagreement should stem from differing judgements, and not from their acting as advocates for their clients.

### **Doctrine of Privity**

Privity indicates a direct contractual relationships. In the past, lack of privity protected design engineers from liability for third party claims (mainly for injuries from construction accidents). It was understood that A/E's were not obligated to protect the workers from safety hazards since they had no contract with them. However, increasingly, the A/E's liability is determined by the tort concept of foreseeability (22). In this context, if a party is negligent in the performance of its duties, it may be held liable to any party who suffered harm that was foreseeable at the time duties were undertaken.

### **Strict Liability**

The doctrine of strict liability generally applies to manufacturers of a product. It is far more stringent than the doctrine of professional liability, since negligence does not have to be proved. However, it must be shown that (21):

- . there was a defect in the product;
- . the defect existed at the time the product was transferred to the purchaser/user;
- . the defect caused or contributed to an injury; and
- . the product failed in normal use.

### **Applicability to A/E's**

Claimants frequently assert that the A/E should also be held strictly liable in tort for injuries caused by allegedly defective designs of inherently dangerous structures. However, several courts have rejected the strict liability doctrine in application to A/E's, viewing the science of engineering and construction as inexact, in that A/E's are not expected to guarantee the satisfactory results of their services. As the Minnesota Supreme Court stated in the *City of Moundsvew vs. Walijarvi* case (23), the clients and A/E's "enjoy a one to one relationship and communicate fairly extensively during the course of the relationship". The court also stated: "Normally an architect has but a single chance to create a design for the client which will produce a defect-free structure." However, in cases where the design-build method is employed in a construction project, the doctrine of strict liability may be applicable.

## **REVIEW QUESTIONS**

1. What is the significance of studying construction and structural failures such as the L'Ambiance Plaza apartments, Willow Island cooling tower and Kansas City Hyatt Regency walkway?
2. Describe from the engineering viewpoint what factors caused the above failures.
3. Synthesize the findings of references (11) and (12) to address the general causes of construction failures.
4. What are the five major classes of causal factors of construction failures according to this module?
5. Describe the role of natural disasters in causing or contributing to failures.
6. What lessons were learned from Hurricane Andrew?
7. Define constructability. What should the designers know about constructability?

8. What are the objectives of constructability reviews?
9. Discuss the relationship between constructability and construction safety.
10. What causes material failures? How do material failures lead to construction failures?
11. How do shop drawings and change orders impact construction site safety?
12. What is the role of the design engineer relative to construction safety?
13. Why must we have a good understanding of the type and magnitude of the construction loads in addition to the service loads of a structure?
14. What is meant by the term temporary structures? What is their significance with regard to construction safety?
15. Define and discuss the terms professional liability, standard of care, privity, and strict liability. Under what conditions could design engineers be held strictly liable for their work?

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## **UNIT VII**

### **CONSTRUCTION SAFETY AND HEALTH MANAGEMENT**

#### **PURPOSE**

To impress upon civil engineering students the significance of a systematic approach to achieving good safety and health in construction projects and to present information on the principles and practice of safety and health management as applicable to construction projects.

#### **OBJECTIVES**

To familiarize the students with:

1. OSHA and ANSI requirements for safety and health management;
2. Elements of an effective construction safety and health program; namely,
  - (a) Top management commitment
  - (b) Goal setting
  - (c) Organization and administration
  - (d) Planning
  - (e) Project safety rules
  - (f) Training and worker orientation
  - (g) Accident investigation and record keeping
  - (h) Safety budget
  - (i) Safety audits
3. Contractual aspects of safety and health management.

#### **KEY TERMS**

OSHA requirements; ANSI standards; BRT model programs; safety and health program; top management commitment; policy statement; goal setting; organization and administration; assignment of responsibilities; communication network; safety meetings; safety committees; safety director; planning; safety rules; training; worker orientation; training resources; accident investigation; record keeping; safety budget; safety audit; safety and health in bids and contracts.

## UNIT VII

### CONSTRUCTION SAFETY AND HEALTH MANAGEMENT

#### **NEED FOR A SAFETY AND HEALTH PROGRAM**

Managers responsible for construction projects must recognize that safety and health must be managed in the same way as cost, schedule, quality and productivity for effective loss control. Management of safety and health deals with managerial decisions and actions taken at all levels to produce an organizational setting in which employees are trained, motivated and supervised to perform work free from injury and illness. Development and implementation of a company safety and health program is key to good management. Safety and health programs are most effective when they are designed to meet the specific and individual needs of each company. It may even be useful to develop one for each project.

#### **OSHA Minimum Requirements**

OSHA (1,2) has set minimum requirements for jobsite safety and health programs for contractors and subcontractors. These requirements can be summarized as follows:

- 1) The employer shall initiate and maintain a jobsite safety and health program.
- 2) No worker will be required to perform work under unsanitary, hazardous or dangerous conditions.
- 3) Frequent and regular inspections of jobsite materials shall be conducted by competent persons.
- 4) Machines, tools and equipment must comply with safety standards, or otherwise be tagged to prevent use, or be removed from the job-site.
- 5) Only employees qualified by training or experience may operate equipment.
- 6) Every employee shall be instructed in the recognition and avoidance of unsafe conditions, and in the safety and the health regulations applicable to his or her work.
- 7) Copies of OSHA rules must be available to workers upon request.
- 8) All fatalities, or accidents resulting in the hospitalization of 5 or more workers must be reported to the OSHA area director.
- 9) A record of all lost-time injuries must be kept and posted at the job-site.
- 10) An employee representative must be given the opportunity to participate in all conferences during OSHA inspections.
- 11) The name and location of the nearest medical facilities must be prominently posted at the jobsite.
- 12) All workers must have access to exposure and medical records.

#### **ANSI Standards**

American National Standards Institute, ANSI (3,4) has issued standards under the titles of "Basic Elements of an Employer Program to Provide a Safe and Healthful Work Environment", and "Construction and

Demolition Operations - Safety and Health Program Requirements for Multi-Employer Projects". These documents provide guidance to employers on how to construct effective programs, and assign responsibilities to personnel.

**Business  
Roundtable  
Model Programs**

The Business Roundtable, BRT (5,6,7,8) has published a number of model safety and health programs to demonstrate success stories on how owners and contractors can promote and achieve excellent safety and health records on their projects. These cases particularly underscore the need for owner involvement in jobsite safety throughout the execution of the construction project.

**SAFETY AND HEALTH  
PROGRAM ELEMENTS**

Depending on the sophistication of the contracting firm, the nature of the project, and owner requirements, a safety and health program can be relatively plain and simple, or highly detailed. In this regard, there is not a unique set of elements for a company safety and health program. We will list and summarize here the key elements believed to be common to successful programs.

**Top Management  
Commitment**

Research (9) has shown that safety starts at the top. Companies in which the chief executive has a strong commitment for safety and health and communicates this concern to employees by word and deed have better safety records than companies for which this is not true. Although chief executives do not normally supervise construction workers on the jobsite, the image they project and the behavior they display on and off the jobsite can have a great impact on the company's safety performance. This can be achieved by:

- . Creating an organizational culture in which safety and health are top priority;
- . Holding line managers accountable for the safety and health of their subordinates; and
- . Focusing on and providing staff support and other necessary resources to help line managers meet their goals on safety and health.

**Policy  
Statement**

A written safety and health policy statement issued by top management is the best way to show the commitment to safety and health; to start the communication of goals and expectations; and to set the ground rules for the delivery of a successful program (10). A typical policy statement is illustrated in Figure VII-1.

**Goal  
Setting**

There needs to be clear goals for the safety and health program at the corporate as well as the project level. These goals need to be communicated to all employees. Goals may include zero fatalities and permanent disability causing injuries, prevention of major fires, vehicle accidents, etc., and full compliance with OSHA standards. The goals set for the program should be measurable to assess whether they are being successfully met.

### **(COMPANY NAME) CORPORATE SAFETY POLICY**

The management of (company name) construction company considers no phase of its operations or administration of greater importance than accident prevention. To accomplish this goal it is therefore necessary that an effective and understandable safety policy be stated and enforced.

This company places the responsibility for workplace safety at all levels of management and on each employee. Each member of the company team must work toward achieving the goal of a safe and healthy workplace.

It is in the interest of safety that this company dedicates itself to providing the highest levels of performances in safety, fire protection, and occupational health consistent with OSHA regulations and nationally recognized standards.

Safety shall be an integral part of each job and each employee shall be responsible for the safety phase of his work just as much as any other phase.

The success of (company name) safety program requires the combined efforts of management, supervision and employees. We want our operations to be among the safest in the construction industry. That goal can only be achieved if every person contributes to this team effort.

Sincerely,

Company CEO

**Figure VII-1. Sample Safety Policy (10)**

## **Organization and Administration**

An organizational and administrative structure should be established to achieve the best results from a safety and health program through line management and support staff. This is possible through setting an effective chain of communication between all levels. There is no set rule as to the proper location of safety and health responsibility in an organization; it is company specific, depending on the need. It is common, however, to have a safety and health department at both the home office of a company, as well as at the individual project level. Usually, the home office serves a staff function, while the field office provides a line function under the project superintendent.

## **Assignment of Responsibilities**

It is important to recognize that safety on the project is everybody's responsibility. Following the commitment of top management comes the assignment of safety duties. Employees at all levels must share in these duties because each employee has a safety duty to every other employee. Safety assignments must be understood by all employees. The right of each employee to a safe work place must be explained and delineated, along with the duty to help keep it that way. It is highly desirable to put the assignments in writing. These might include individual responsibilities for program accomplishment and/or compliance for the company's president, management, jobsite superintendents, safety staff, foremen, craft personnel, subcontractors, suppliers, architect/ engineers, owner personnel, and visitors. Accountability should also be addressed stating how incentives are distributed or disciplinary actions will be taken.

## **Communication Network**

Maintaining an effective communication network on the jobsite is key to successful safety and health management. Managers can accomplish this by the chain of command system, direct contacts, and group meetings. The chain of command system alone has drawbacks since it can lead to distorted or "filtered" information through the hierarchy which may provide misleading data on which to act. Managers who walk through the job frequently and talk directly with the site personnel can create a medium of effective two-way communication and convey their safety and health priorities. It is better when they share information with workers and foremen and listen to their feedback, rather than just issuing orders. This way the integrity of the chain of command system is not undermined. It is also important that follow-up action is taken to address the issues discussed with the site personnel. Otherwise, the interest in participation may dwindle.

## **Meetings**

Meeting with different supervisory groups and groups of craft workers can also be very effective. They may be regularly scheduled or ad hoc, or may be part of a project meeting (i.e. as an agenda item). Safety meetings serve a good purpose for planning, or may address specific problems. Toolbox meetings are particularly useful exchanging information, and providing for continuing training to the workers. Research (9) has shown that toolbox meetings addressing specific job

safety problems make more positive impact on the safety record of the company than those covering generalities. Safety committees are established in some jobs to address a range of issues which cover planning, training and audits (11). The effectiveness of safety committees is open to question, however, because delegation of responsibility to a committee by the management personnel may actually dilute their commitment and active participation.

## **Safety Director**

The safety supervisor/director plays an important role in the implementation of the safety program. These professionals are usually in staff positions rather than line positions, as safety is a staff responsibility. They provide support to the line managers who actually control safety and health performance. Among their duties are:

### *Duties*

- . Serving as consultants to management on technical and organizational aspects of safety and health;
- . Developing and participating in the training and worker orientation programs;
- . Assisting in safety and health planning, monitoring (jobsite supervision) and recordkeeping; and
- . Keeping the organization up-to-date on safety and health regulations and related matters.

In situations of imminent danger, they can take steps to shut down jobs.

## **Planning**

There needs to be a project specific safety and health plan prepared by the contractor in addition to any previously prepared manual the company might have. This plan should address the operational and task hazards, owner's requirements, and unique problems which may be potentially encountered. Planning for safety is an on-going process, starting in the bid process and continuing through the completion of all of the project tasks on the jobsite. According to Levitt and Samelson (9), there are three levels of planning: "big scale planning," "small rolling-window planning," and "fine-tune planning." Big-scale planning covers such areas as site planning and the development of work procedures for basic tasks including equipment and material usage. It begins before the project starts, but it also continues on a regular basis in order to keep the big picture of the project in mind and up to date. Small rolling-window planning takes a two-week rolling window view of the total job; the coming week is planned and planning is begun on the following week. Fine-tune planning is daily planning for the current week and concerns immediate operations and production.

## **Project Safety Rules**

All company safety rules should be published in a written form. Written rules are more easily enforced, and provide readily available guidance for operational safety. These rules should include what penalties are given for non-compliance. Each current employee, as well as any new employee, should be furnished a copy of the safety rules.

### *Nature of the Rules*

Each contractor should have rules for basic types of operations it performs. In some cases there should be rules for the different

company divisions or crews. Also, these rules should be modified as site conditions or owner requirements dictate. These work practices may be simple, one-page handouts for specific operations like erecting scaffolds, excavating trenches, or operating specific pieces of equipment. Depending on the situation, the safety rules may also be very involved based on a hazard analysis for critical tasks. In any event, there should be a list of general rules for everyone, such as those shown in Figure VII-2. Rules must be concise and easy to understand. They are instructions to field personnel for safe working procedures, and therefore must be in a format which can easily be implemented in the field.

### **Training and Worker Orientation**

Training and worker orientation are necessary elements of an effective safety and health program. OSHA mandates employee training; see, for example, 1926.21 (b)(2). There are two types of training:

- 1) Training for specific tasks; and
- 2) General training in accident avoidance and prevention.

It is desirable to integrate these efforts and train employees in safety and health as part of craft training (12).

### *Ways to Train Employees*

There are several ways to provide employee training. Discussions at weekly toolbox meetings are an effective training method. Many insurance companies and trade associations, such as the Associated General Contractors (AGC), provide "tool box talks" to assist employers in the selection and delivery of safety topics. Private subscription services are also available to provide new topics on a regular basis.

### *Training Resources*

Many insurance companies conduct safety seminars on the jobsite as part of their services associated with the workers compensation coverage. This type of training can be utilized effectively before employees start work, or on specific hazardous operations. Local Safety councils and trade associations may provide free or low-cost training programs. These programs are tailor-made to meet specific training requirements. Many academic institutions also offer extensive safety courses. Finally, safety consultants provide both training and training program evaluation services. All training efforts must be carried out by qualified persons, who are capable of stimulating and motivating the trainees.

### **New Worker Orientation**

A significant component of the company safety and health training program is new worker orientation. New construction workers, and workers starting on an entirely new activity without previous experience, are particularly susceptible to being injured. The objectives of the orientation program are to relieve beginner anxieties, indoctrinate the workers to the company's safety program, and teach safe work practices which includes the use of personal protective equipment. Each employee should be handed a set of company safety rules during

## GENERAL SAFETY RULES

**ALL OF OUR SAFETY RULES MUST BE OBEYED. FAILURE TO DO SO WILL RESULT IN STRICT DISCIPLINARY ACTION BEING TAKEN.**

1. Keep your mind on your work at all times. No horseplay on the job. Injury or termination, or both, can be the result.
2. Personal safety equipment must be worn as prescribed for each job, such as; safety glasses for eye protection; hard hats at all times within the confines of the construction area; gloves when handling materials; and safety shoes are highly recommended for protection against foot injuries.
3. Shirts and long legged pants must be worn to prevent sunburn and to protect against acid burns, steam burns, weld splatter and cuts. Minimum clothing for the upper body is a "T" shirt.
4. If any part of your body should come in contact with an acid or caustic substance, rush to the nearest water available and flush over the affected part. Secure medical aid immediately.
5. Watch where you are walking. Don't run.
6. The use of illegal drugs or alcohol or being under the influence of same on the project shall be cause for termination. If you take or are given strong prescription drugs that warn against driving or using machinery, let your supervisor know about them.
7. Do not distract the attention of fellow workers. To do so may cause injury.
8. Sanitation facilities have been or will be provided for your use. Defacing or damaging these facilities is forbidden.
9. A good job is a clean job and a clean job is a safe one. So keep your working area free from rubbish and debris.
10. Do not use a compressor to blow dust or dirt from your clothes, hair, face or hands.
11. Never work aloft if you are afraid to do so, are subject to dizzy spells, or if you are apt to be nervous or sick.
12. Never move an injured person unless it is absolutely necessary. Further injury may result. Keep the injured as comfortable as possible and utilize job site first-aid facilities until a doctor arrives.
13. Know where firefighting equipment is located and learn how to use it.
14. Learn to lift correctly - with the legs not the back. If the load is too heavy, **GET HELP**. 20% of all construction related injuries result from lifting materials.
15. Riding on loads, fenders, running boards, sideboards, and gates or with your legs hanging over the ends or sides of trucks will not be tolerated.
16. Do not use power tools and equipment until you have been properly instructed in safe work methods and become authorized to use them.

Figure VII-2. Sample General Safety Rules

17. Be sure that all guards are in place. Do not remove, displace, damage, or destroy any safety device or safeguard furnished or provided for use on the job, nor interfere with the use thereof.
18. Do not enter an area which has been roped off or barricaded.
19. If you must work around power shovels, cranes, trucks, and dozers, make sure operators can always see you.
20. Never oil, lubricate or fuel equipment while it is running or in motion.
21. Rope off barricade danger areas.
22. Keep away from the edge of cuts, embankments, trenches, holes and/or pits.
23. Trenches must be shored or sloped to comply with the most stringent requirements. Keep out of trenches or cuts that have not been properly sloped or shored. Excavated or other material shall not be stored nearer than 3 feet from the edge of any excavation.
24. Use the "four and one" rule when using a ladder. One foot of base for every four feet of height.
25. Always secure the bottom of the ladder with cleats and/or safety feet. Lash off the top of ladder to avoid shifting.
26. Ladders must extend three feet above a landing for proper use.
27. Defective ladders must be properly tagged and removed from service.
28. Keep ladder base free of debris, hoses, wires, material, etc.
29. Build scaffolds according to manufacturers' recommendations.
30. Scaffold planks must be cleated or secured to prevent them from sliding.
31. Use only extension cords of the three prong type. Check the electrical grounding system daily.
32. The use of safety belts with safety lines when working from unprotected high places is mandatory. Always keep your line as tight as possible.
33. Tar kettles must be kept at least 25 ft. from buildings or structures and never on roofs.
35. Open fires are prohibited.
36. Know what emergency procedures have been established for your job site. (Location of Emergency Phone, First Aid Kit, Stretcher location, Fire Extinguishers location, Evacuation Plan, etc.)
37. Notify your supervisor of unlabeled or suspect toxic substances immediately and avoid contact.

*The information contained herein in no way relieves suppliers or contractors of their lawful or contractual responsibilities and obligations for safety. Suppliers and/or subcontractors should seek professional guidance (legal / safety) in developing their own safety rules and programs.*

**Figure VII-2. (Continued)**

orientation and should be encouraged to read and understand them thoroughly.

### **Keeping Records of Training**

It is recommended that for all safety training, companies keep written records of:

- . Topics covered;
- . Times, dates and locations of the training activities;
- . Names of the employees in attendance; and
- . Acknowledgement of the employees having received the particular training by signing off.

This will help avoid unnecessary duplication and provide documentation which can protect the company against OSHA citations and lawsuits.

### **Accident Investigation and Record Keeping**

As previously covered in Unit IV, accident investigations can highlight problem areas, and help detect patterns of unsafe acts or conditions which should be addressed in preventive efforts. In this regard, accident reports make excellent training tools. Every accident, including those without injury should be investigated as part of the company safety and health program. The recordkeeping requirements previously covered are also an important element of the safety and health program. A thorough and continuous recordkeeping system for recordable cases, accident investigations, safety training programs, test results, etc. provide managers with significant information management capability for good decision making, while meeting OSHA and other mandates.

### **Safety Budget**

A company truly interested in safety will include a budget covering safety program expenses, such as costs of safety personnel, training, protective equipment, first aid station maintenance, etc. An advanced program will include these safety costs showing them as part of direct labor. An enhanced program will be able to demonstrate these costs as part of operational or task performance, such as a percentage of each cubic yard of concrete poured. Contractors should be required to show that they are prepared to allocate resources for safety supervision, joint consultation, training, safety equipment, and other necessary safety program assets in relation to the size and nature of the project (13).

### **Safety Audits**

Safety and health audits measure the program's effectiveness. Audits include both field inspections and overall program evaluation. One of the better tools for enhancing safety programs is a system of frequent on-site inspections. These inspections, or field audits, provide immediate and tangible evidence of the performance level of a safety program, as well as providing for direct observation of any present or developing site hazards. On-site inspections keep safety at the forefront and insure a high degree of compliance with the rules. Safety audits should be an on-going activity throughout the project.

### **Management Role**

Inspections may be performed by owner representatives, site superintendents, foremen, or the company safety staff. The advantages

of the management's performing the audits are: (a) management is primarily responsible for safety; (b) managers control work performance, and (c) supervisors should know the hazards on the jobsite. The main disadvantage is the possibility of a conflict of interest. There may be a tendency to overlook or minimize some situations which might imply negligence on management's part. This problem can be alleviated when safety professionals perform the audits.

#### **Items for Inspection**

There are numerous items which can be targeted for inspection and jobsite observation. From a hazard standpoint, these may include housekeeping and sanitation, fire prevention, electrical installations, hand and power tools, ladders, scaffolding, cranes, hoists and derricks, heavy equipment, motor vehicles, barricades, handling and storage of materials, excavation and shoring, demolition, hazardous materials, welding and cutting, personal protective equipment, concrete and masonry construction, steel erection, and others.

#### **OSHA's Role**

There are different options to approaching field audits. Some types of inspections are mandated by OSHA and can be found as specific requirements, such as the inspection of excavations by a competent person. In reality, all OSHA standards constitute items for inspection from the OSHA compliance officer's viewpoint. This provides pressure on the contractor to perform self-inspection of the worksite.

#### **Elements of a Comprehensive Audit**

A comprehensive safety and health program audit may include the following key elements (14):

- . Degree of management commitment
- . Presence and effectiveness of the policy statement
- . Program goal setting
- . Definition of safety responsibilities
- . Experience modification rating (over 2-3 years)
- . Management supervisory meetings
- . Pre-planning for jobsite safety
- . Effectiveness of training and orientation programs
- . Accident investigation activities
- . Record keeping
- . Substance abuse policy
- . Safety budget
- . Field performance audits.

#### **CONTRACTUAL ASPECTS**

Incorporation of safety and health in construction contracts can make a significant and positive impact on the project's safety and health performance. One effective way of doing this is to establish target safety and health standards and criteria for the project. The CICE Southeastern Michigan Study Group (15) has suggested that such standards must include a well-ordered and maintained site clean-up program, and a unified site safety and health program. Further, the group has suggested that the contractual requirements of the safety and health program should address the following:

- . An individual designated by the successful bidder (as contractor) must be assigned as safety manager.
- . There must be a plan to put the safety and health program in place on the first day of work on the contract, and to assure that each worker understands the program, that the program will be followed consistently, and that there will be accountability for violations.
- . There must be appropriate work environment safety and health training (e.g. tool box meetings) selected for the construction procedures being carried out by the contractor and its subcontractors, with a record made, at each meeting, of the name of the discussion leader, the topics discussed and the names of those in attendance.
- . A monthly safety audit must be conducted by the contractor's safety manager with procedures established for the audit to be reviewed by the contractor's management and members of the project team.
- . There must be an appropriate substance abuse awareness program.

With regard to the target safety and health criteria for the project, the following have been suggested by the CICE group:

- . A worker's compensation experience modification rate (EMR) for bidder and on-site, first tier subbidders should be at or below a specified value on date of bid. For verification of the EMR rate, the bidder and its on-site, first tier subbidders can provide confirmation by providing a copy of the worker's compensation policy declaration page or a letter from their insurance carrier.
- . Recordable incidence rates, based on OSHA Form No. 200 data, should be maintained throughout the duration of the contract at or above the values stated by bidder and its subbidders, unless other criteria are agreed upon between owner and bidder. For verification of the OSHA incidence rates, the bidder and its subbidders can provide a copy of their last calendar year report.

#### **AIA Article 10**

The American Institute of Architects (AIA) document on General Conditions of the Contract for Construction (16) includes a section (Article 10) for protection of persons and property, which addresses the safety and health aspects of a project. The contents of this section are presented in Figure VII-3.

#### **Safety and Health as a Bid Item in Contracts**

Inclusion of safety and health in construction contracts places the required emphasis on their significance, and encourages the contractor to pay systematic attention to safety and health. However, safety is usually not a pay item in the contract, and its costs are lumped into the "cost of doing business", or the project overhead. At the National Forum on Construction Safety and Health Priorities (17), it was strongly suggested that safety and health be included in the contracts as a bid item just like excavation, borrow material, concrete, etc. This will make owners pay for this item separately; however, it will provide the resources to contractors to invest in safety and health appropriately, delivering improved performance.

## ARTICLE 10

### PROTECTION OF PERSONS AND PROPERTY

#### 10.1 SAFETY PRECAUTIONS AND PROGRAMS

10.1.1 The Contractor shall be responsible for initiating, maintaining and supervising all safety precautions and programs in connection with the performance of the Contract.

10.1.2 In the event the Contractor encounters on the site material reasonably believed to be asbestos or polychlorinated biphenyl (PCB) which has not been rendered harmless, the Contractor shall immediately stop Work in the area affected and report the condition to the Owner and Architect in writing. The Work in the affected area shall not thereafter be resumed except by written agreement of the Owner and Contractor if in fact the material is asbestos or polychlorinated biphenyl (PCB) and has not been rendered harmless. The Work in the affected area shall be resumed in the absence of asbestos or polychlorinated biphenyl (PCB), or when it has been rendered harmless, by written agreement of the Owner and Contractor, or in accordance with final determination by the Architect on which arbitration has not been demanded, or by arbitration under Article 4.

10.1.3 The Contractor shall not be required pursuant to Article 7 to perform without consent any Work relating to asbestos or polychlorinated biphenyl (PCB).

10.1.4 To the fullest extent permitted by law, the Owner shall indemnify and hold harmless the Contractor, Architect, Architect's consultants and agents and employees of any of them from and against claims, damages, losses and expenses, including but not limited to attorneys' fees, arising out of or resulting from performance of the Work in the affected area if in fact the material is asbestos or polychlorinated biphenyl (PCB) and has not been rendered harmless, provided that such claim, damage, loss or expense is attributable to bodily injury, sickness, disease or death, or to injury to or destruction of tangible property (other than the Work itself) including loss of use resulting therefrom, but only to the extent caused in whole or in part by negligent acts or omissions of the Owner, anyone directly or indirectly employed by the Owner may be liable, regardless of whether or not such claim, damage, loss or expense is caused in part by a party indemnified hereunder. Such obligation shall not be construed to negate, abridge, or reduce other rights or obligations of indemnity which would otherwise exist as to a party or person described in this Subparagraph 10.1.4.

#### 10.2 SAFETY OF PERSONS AND PROPERTY

10.2.1 The Contractor shall take reasonable precautions for safety of, and shall provide reasonable protection to prevent damage, injury or loss to:

- 1 employees on the Work and other persons who may be affected thereby;
- 2 the Work and materials and equipment to be incorporated therein, whether in storage on or off the site, under care, custody or control of the Contractor or the Contractor's Subcontractors or Sub-subcontractors; and

- 3 other property at the site or adjacent thereto, such as trees, shrubs, lawns, walks, pavements, roadways, structures and utilities not designed for removal, relocation or replacement in the course of construction.

10.2.2 The Contractor shall give notices and comply with applicable laws, ordinances, rules, regulations and lawful orders of public authorities bearing on safety of persons or property or their protection from damage, injury or loss.

10.2.3 The Contractor shall erect and maintain, as required by existing conditions and performance of the Contract, reasonable safeguards for safety and protection, including posting danger signs and other warnings against hazards, promulgating safety regulations and notifying owners and users of adjacent sites and utilities.

10.2.4 When use or storage of explosives or other hazardous materials or equipment or unusual methods are necessary for execution of the Work, the Contractor shall exercise utmost care and carry on such activities under supervision of properly qualified personnel.

10.2.5 The Contractor shall promptly remedy damage and loss (other than damage or loss insured under property insurance required by the Contract Documents) to property referred to in Clauses 10.2.1.2 and 10.2.1.3 caused in whole or in part by the Contractor, a Subcontractor, Sub-subcontractor, or anyone directly or indirectly employed by any of them, or by anyone for whose acts they may be liable and for which the Contractor is responsible under Clauses 10.2.1.2 and 10.2.1.3, except damage or loss attributable to acts or omissions of the Owner or Architect or anyone directly or indirectly employed by either of them, or by anyone for whose acts either of them may be liable, and not attributable to the fault or negligence of the Contractor. The foregoing obligations of the Contractor are in addition to the Contractor's obligations under Paragraph 3.18.

10.2.6 The Contractor shall designate a responsible member of the Contractor's organization at the whose duty shall be the prevention of accidents. This person shall be the Contractor's superintendent unless otherwise designated by the Contractor in writing to the Owner and Architect.

10.2.7 The Contractor shall not load or permit any part of the construction or site to be loaded so as to endanger its safety.

#### 10.3 EMERGENCIES

10.3.1 In an emergency affecting safety of persons or property, the Contractor shall act, at the Contractor's discretion, to prevent threatened damage, injury or loss. Additional compensation or extension of time claimed by the Contractor on account of an emergency shall be determined as provided in Paragraph 4.3 and Article 7.

Figure VII-3. AIA Article on Protection of Persons and Property (16)

## **REVIEW QUESTIONS**

1. Why do engineering and construction firms need a safety and health program?
2. Summarize OSHA's minimum requirements for jobsite safety and health programs for contractors and subcontractors.
3. Why should owners be involved in jobsite safety?
4. Describe the elements of an effective safety and health program.
5. What should go into a policy statement prepared by top management?
6. What is the best way to organize and administer a jobsite safety and health program?
7. Why has the effectiveness of safety committees been questioned?
8. What are the duties of a safety director in a company?
9. What are the three levels of planning performed as part of a safety and health program?
10. Why should there be a set of project safety rules?
11. Describe how safety and health training and worker orientation can best be implemented by a company.
12. What is the significance of having a safety budget in a construction project?
13. What is a safety audit? List the key elements of a comprehensive audit.
14. Why should safety and health be a part of a construction contract? What should the contractual requirements address regarding safety and health?

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**NIOSH**

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**ALERT**

**JULY 1985**

**Request for Assistance in Preventing  
Electrocutions from Contact Between  
Cranes and Power Lines**

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
PUBLIC HEALTH SERVICE  
CENTERS FOR DISEASE CONTROL  
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

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REQUEST FOR ASSISTANCE IN PREVENTING  
ELECTROCUTIONS FROM CONTACT BETWEEN CRANES AND POWER LINES

**BACKGROUND**

Contact between cranes and overhead power lines is a major cause of fatal occupational injuries in the United States. Based upon an analysis by the National Institute for Occupational Safety and Health (NIOSH) of the data from the Supplementary Data System [1] of the Bureau of Labor Statistics, there were approximately 2,300 lost workday occupational injuries in the United States in 1981 which resulted from contact with electrical current by crane booms, cables, or loads. These 2,300 injuries were extremely severe, resulting in 115 fatalities and 200 permanent total disabilities. Comparable statistics obtained in studies conducted by the National Safety Council from 1964 to 1976 produced an estimated annual average of 150 fatalities resulting from such incidents [2]. NIOSH believes that this type of event is the most common cause of fatalities associated with mobile crane operations [3] and is responsible for approximately 1.5% of all fatal work-related injuries each year.

**CASE REPORTS**

As part of the Fatal Accident Circumstances and Epidemiology (FACE) Project conducted by NIOSH, six fatal injuries involving crane-related electrocutions were investigated. The synopses of these cases are as follows:

**Case #1:**

A 28-year-old construction worker was holding on to a steel ladder being moved by a telescoping boom crane. As the crane's boom was swung in the direction of 7,200 volt power lines, the cable contacted the closest of the lines and the worker was electrocuted.

**Case #2:**

A co-owner of a steel erection company and three workers were using a telescoping boom crane to move a section of a steel framing member at the construction site of a commercial storage shed. As the section was moved, it came into contact with a 23,000 volt overhead power line. Two of the three workers who were in direct contact with the load were electrocuted while the third received serious electrical burns.

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Between Cranes and Power Lines

Case #3:

Roof materials for an addition to a commercial building were stored outside the building directly beneath a 7,200 volt power line. While hooking a load (joist angle bracing) to the crane, a worker was electrocuted when the cable came into contact with the power line as the boom swung.

Case #4:

A construction company was in the process of laying concrete water pipe with a crane. As workmen were placing support timbers beneath the crane's outrigger pads, the operator began extending the crane boom for the next lift when the boom came into contact with a 3 phase 13,800 volt overhead power line. One worker touching an outrigger of the crane was electrocuted.

Case #5:

At a highway construction site, a carpenter attached a 4' x 8' wood and metal form to a crane. While holding on to the form in attempting to guide it into place, the carpenter was electrocuted when the boom or cable came into contact with a 34,000 volt power line.

APPROPRIATE STANDARDS AND RECOMMENDED WORK PRACTICES

The Occupational Safety and Health Administration (OSHA) Safety and Health Regulations for Construction, Subpart N--Cranes, Derricks, Hoists, Elevators, and Conveyors (29 CFR 1926.550(a)(15)) contains specific requirements for the safe use of cranes proximate to overhead power lines. Electrical distribution and transmission lines are required to be de-energized and visibly grounded, moved, or separated from cranes with independent insulating barriers. The regulation states that when it is not possible to meet these requirements, cranes may operate proximate to power lines only if:

- a) minimum clearance (absolute limit of approach) is maintained between the crane and the lines (10 feet for  $\leq 50$  kV and 10 feet plus 0.4 inch for each 1 kV over 50 kV, or twice the length of the line insulator but never less than 10 feet); or,
- b) in transit with no load and boom lowered, minimum clearance (absolute limit of approach) is maintained (4 feet for  $\leq 50$  kV, 10 feet for 50 kV to 345 kV, or 16 feet for up to and including 750 kV).

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Between Cranes and Power Lines

Additionally, 1926.550(a)(15) requires that: a person be designated to observe the clearance of the crane when it is difficult for the crane operator to use direct observation; cage-type boom guards, insulating lines, or proximity warning devices may be used, but their use does not eliminate the need to adhere to the other parts of the regulation; any overhead wire is to be considered energized until the owner of the line or the electric utility indicates that it is not energized and that it has been visibly grounded; transmitter towers should also be de-energized or tests shall be conducted to determine if an electrical charge has been induced on the crane. Induced charges shall be dissipated by providing an electrical ground directly to the upper rotating structure supporting the boom; ground jumper cables shall be attached to materials when an electrical charge is induced; crews shall be provided with nonconductive poles to attach the ground cable to the load; combustible and flammable materials shall be removed from the immediate area prior to operations.

The Construction Safety Association of Ontario, Canada (CSA-Ontario), recommends safe work practices [4] beyond those addressed in the OSHA standard including the use of nonconductive taglines to guide loads and the use of insulating personal protective equipment by exposed workers.

#### APPLICATION OF EXISTING STANDARDS AND RECOMMENDED WORK PRACTICES

Table 1 presents an analysis for each of the five cases described in this alert regarding compliance with the OSHA standard or CSA-Ontario recommended work practices. In two of the cases, neither the OSHA standard nor the CSA-Ontario recommended work practices were being followed. In the remaining three cases, only one of these safe work practices (avoiding the storage of materials directly under power lines) was being followed. In each of these five cases, there was demonstrable lack of compliance with the OSHA standard.

#### CONCLUSION

The principal objective of the investigations undertaken by NIOSH as part of its Fatal Accident Circumstances and Epidemiology (FACE) Project is to determine what factors enabled the fatality to occur. The goal is to learn how such fatalities can be prevented. In this context, whether or not an operation was "in compliance" with existing standards is but one of many variables which may or may not have contributed to the fatality. However, in the course of the investigations reported here, it became obvious that full compliance with relevant OSHA standards and full use of the CSA-Ontario work practices would have prevented each fatality.

As an obvious first step in preventing such fatalities in the future, we conclude that all such operations should be done only in compliance with existing OSHA standards.

TABLE 1

Status of Compliance with OSHA Standards (or Use of CSA-Ontario  
Recommended Work Practices) in Operations Which Resulted in  
Six Crane-related Electrocutions

Relevant OSHA Standard (or CSA-Ontario Recommended Work Practice)	Status of Compliance by Case				
	<u>#1</u>	<u>#2</u>	<u>#3</u>	<u>#4</u>	<u>#5</u>
1. Move, insulate, or de-energize power line before starting work (OSHA)	No	No	No	No	No
2. Maintain recommended absolute limit of approach (minimum clearance) for specific voltage (OSHA)	No	No	No	No	No
3. Utilize a signal man (OSHA)	No	No	No	No	No
4. Utilize nonconductive taglines, rather than direct contact, to stabilize load (CSA-Ontario)	No	No	No	No	No
5. Do not store combustible materials directly beneath power lines (OSHA & CSA-Ontario)	No	Yes	No	Yes	Yes
6. Use boom guards, insulating lines, or proximity warning devices in addition to other requirements (OSHA)	No	No	No	No	No
7. Use insulating boots and gloves when workers connect loads or contact the crane while in the vicinity of overhead power lines (CSA-Ontario)	No	No	No	No	No

No = Data demonstrated lack of compliance with the OSHA standard (or lack of  
use of CSA-Ontario recommended work practices).

Yes = Data demonstrated compliance with the OSHA standard (or use of  
CSA-Ontario recommended work practices).

Page 5 - Request for Assistance in Preventing Electrocutions from Contact  
Between Cranes and Power Lines

RECOMMENDATIONS BY NIOSH

The existing OSHA standard appears sufficient to prevent the crane-related electrocutions described in this alert as well as all others. NIOSH urges all employers who use cranes in the vicinity of overhead power lines to familiarize themselves with and implement the existing OSHA standard. NIOSH urges safety and trade associations, crane manufacturers, electric utility companies, and OSHA state consultative services to bring this standard to the attention of employers who use cranes. Implementation of the work practices described by the CSA of Ontario can provide an additional margin of safety.

Suggestions, requests for additional information on safe work practices, or questions related to this announcement should be directed to Mr. John Moran, Director, Division of Safety Research, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505-2888, Telephone (304) 291-4595.

We greatly appreciate your assistance.

A handwritten signature in dark ink, appearing to read "J. Millar", followed by a smaller, less distinct signature or set of initials.

J. Donald Millar, M.D., D.T.P.H., (Lond.)  
Assistant Surgeon General  
Director, National Institute for  
Occupational Safety and Health  
Centers for Disease Control

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# **ALERT**

## **Request for Assistance in Preventing Occupational Fatalities in Confined Spaces**

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## **REQUEST FOR ASSISTANCE IN PREVENTING OCCUPATIONAL FATALITIES IN CONFINED SPACES**

### **SUMMARY**

This Alert requests the assistance of managers, supervisors, and workers in the prevention of deaths that occur in confined spaces. Confined spaces may be encountered in virtually any occupation; therefore, their recognition is the first step in preventing fatalities. Since deaths in confined spaces often occur because the atmosphere is oxygen deficient or toxic, confined spaces should be tested prior to entry and continually monitored. More than 60% of confined space fatalities occur among would-be rescuers; therefore, a well-designed and properly executed rescue plan is a must. This Alert describes 16 deaths that occurred in a variety of confined spaces. Had these spaces been properly evaluated prior to entry and continuously monitored while the work was being performed and had appropriate rescue procedures been in effect, none of the 16 deaths would have occurred. There are no specific OSHA rules that apply to all confined spaces. Recommendations for Recognition, Testing, Evaluation, and Monitoring, and Rescue of Workers are presented. Other National Institute for Occupational Safety and Health (NIOSH) publications on this subject as well as a source for additional information and assistance are also presented.

January 1986

## BACKGROUND

The deaths of workers in confined spaces constitute a recurring occupational tragedy; approximately 60% of these fatalities have involved would-be rescuers. If you are required to work in a:

SEWER  
SEPTIC TANK  
SEWAGE DIGESTER  
PUMPING/LIFT STATION  
SEWAGE DISTRIBUTION  
or HOLDING TANK

STORAGE TANK  
SILO  
VAT  
DUCT  
UTILITY VAULT

SHIP'S HOLD  
REACTION VESSEL  
BOILER  
PIPELINE  
PIT

or similar type of structure or enclosure, you are working in a **CONFINED SPACE**. The Occupational Safety and Health Administration (OSHA) defines a confined space in 29 CFR 1926.21 as "any space having a limited means of egress, which is subject to the accumulation of toxic or flammable contaminants or has an oxygen deficient atmosphere." The NIOSH Criteria for a Recommended Standard....Working in Confined Spaces dated December, 1979, defines a confined space as:

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

## CASE REPORTS OF FATAL INCIDENTS

### Case #1 - RECOGNITION AND RESCUE (FATALITIES = 1 WORKER + 1 RESCUER)

On December 29, 1983, a 54-year-old worker died inside a floating cover of a sewage digester while attempting to restart a propane heater that was being used to warm the outside of the sewage digester cover prior to painting it. Workers had wired the safety valve open so that the flow of propane would be constant, even if the flame went out. The heater was located near an opening in the cover of the digester. When the worker attempted to restart the heater, an explosion occurred that vented through the opening. The worker crawled away from the heater into an area that was oxygen deficient and died. A co-worker attempted a rescue and also died.

### Case #2 - RECOGNITION AND RESCUE (FATALITIES = 1 WORKER + 1 RESCUER)

On March 8, 1984, a 20-year-old construction worker died while attempting to refuel a gasoline engine powered pump used to

Page 3 - Request for Assistance in Preventing Occupational Fatalities in Confined Spaces

remove waste water from a 66 inch diameter sewer line that was under construction. The pump was approximately 3,000 feet from where the worker had entered the line. The worker was overcome by carbon monoxide. A co-worker, who had also entered the sewer line, escaped. A 28-year-old state inspector entered from another point along the sewer line and died in a rescue attempt. Both deaths were due to carbon monoxide intoxication. In addition to the fatalities, 30 firefighters and 8 construction workers were treated for carbon monoxide exposure.

**Case #3 - RECOGNITION AND RESCUE (FATALITIES = 2 RESCUERS)**

On October 4, 1984, two workers (26 and 27 years old) were overcome by gas vapors and drowned after rescuing a third worker from a fracturing tank at a natural gas well. The tank contained a mixture of mud, water, and natural gas. The first worker had been attempting to move a hose from the tank to another tank. The hose was secured by a chain and when the worker moved the hose, the chain fell into the tank. The worker entered the tank to retrieve the chain and was overcome.

**Case #4 - RECOGNITION AND RESCUE (FATALITIES = 1 WORKER + 1 RESCUER)**

On December 5, 1984, a 22-year-old worker died inside a toluene storage tank that was 10 feet in diameter and 20 feet high while attempting to clean the tank. The worker entered the tank through the 16 inch diameter top opening using a 1/2 inch rope for descent. Although a self-contained breathing apparatus was present, the worker was not wearing it when he entered the tank. The worker was overcome and collapsed onto the floor of the tank. In an attempt to rescue the worker, fire department personnel began cutting an opening into the side of the tank. The tank exploded, killing a 32-year-old firefighter and injuring 15 others.

**Case #5 - RECOGNITION AND RESCUE (FATALITIES = 1 WORKER + 1 RESCUER)**

On May 13, 1985, a 21-year-old worker died inside a waste water holding tank that was four feet in diameter and eight feet deep while attempting to clean and repair a drain line. Sulfuric acid was used to unclog a floor drain leading into the holding tank. The worker collapsed and fell face down into six inches of water in the bottom of the tank. A second 21-year-old worker attempted a rescue and was also overcome and collapsed. The first worker was pronounced dead at the scene and the second worker died two weeks later. Cause of death was attributed to asphyxiation by methane gas. Sulfuric acid vapors may have also contributed to the cause of death.

**Case #6 - RECOGNITION AND RESCUE (FATALITY = 1 RESCUER)**

On June 7, 1985, a 43-year-old father died while attempting to rescue his 28-year-old son from a tank used to store spent acids from a metal pickling process. The tank was out of service so that sludge could be removed from the bottom. The son collapsed in the tank. The father attempted a rescue and also collapsed. The two were removed from the tank; the son was revived, but the father died. The cause of death is unknown.

**Case #7 - RECOGNITION (FATALITY = 1 WORKER)**

On July 2, 1985, a crew foreman became ill and was hospitalized after using an epoxy coating, which contained 2-nitropropane and coal tar pitch, to coat a valve on an underground waterline. The valve was located in an enclosed service vault (12' x 15' x 15'). The worker was released from the hospital on July 3, 1985, but was readmitted on July 6, 1985; he lapsed into a coma and died on July 12, 1985, as a result of acute liver failure induced by inhalation of 2-nitropropane and coal tar pitch vapors. A co-worker was also hospitalized, but did not die.

**Case #8 - RECOGNITION AND RESCUE (FATALITIES = 1 WORKER + 3 RESCUERS)**

On July 5, 1985, a 27-year-old sewer worker entered an underground pumping station (8' x 8' x 7') via a fixed ladder inside a three foot diameter shaft. Because the work crew was unaware of procedures to isolate the work area and ensure that the pump had been bypassed, the transfer line was still under pressure. Therefore, when the workers removed the bolts from an inspection plate that covered a check valve, the force of the waste water blew the inspection plate off, allowing sewage to flood the chamber, and trapping one of the workers. A co-worker, a supervisor, and a policeman attempted a rescue and died. The first two deaths appeared to be due to drowning and the latter two appeared to be due to asphyxiation as a result of inhalation of "sewer gas."

**REGULATORY STATUS**

As stated in the Regulatory Program of the United States Government (Confined Spaces [29 CFR 1910], page 282 dated August, 1985), "there are no specific OSHA rules directed toward all confined-space work, forcing OSHA compliance personnel to cite other marginally applicable standards or section 5(a)(1) in cases involving confined spaces. For this reason, OSHA field personnel have frequently and strongly recommended the promulgation of a specific standard on confined spaces." In the document Criteria for a Recommended Standard....Working in Confined Spaces, the National Institute for Occupational Safety and Health (NIOSH) has provided comprehensive

**Page 5 - Request for Assistance in Preventing Occupational Fatalities in  
Confined Spaces**

recommendations for assuring the safety and well-being of persons required to work in confined spaces including a proposed classification system and checklist that may be applied to different types of confined spaces.

**CONCLUSIONS**

The case studies described above are summarized in Table 1 (see page 6):

TABLE I

SELECTED CHARACTERISTICS OF INCIDENTS OF OCCUPATIONAL FATALITY IN CONFINED SPACE

<u>CASE</u>	<u>DATE</u>	<u>TYPE OF SPACE</u>	<u>TYPE OF HAZARD</u>	<u>DEATHS</u>			<u>COMMENT</u>
				<u>WORKER</u>	<u>RESCUER</u>	<u>TOTAL</u>	
#1	12/29/83	Sewage digester	Oxygen deficiency	1	1	2	-
#2	3/8/84	Sewer line construction	Toxic atmosphere; physical hazard	1	1	2	38 others injured
#3	10/4/84	Fracturing tank	Oxygen deficiency	0	2	2	2 rescuers drowned
#4	12/5/84	Toluene storage tank	Toxic atmosphere; explosion; limited entry and exit	1	1	2	15 others injured
#5	5/13/85	Waste water tank	Toxic atmosphere; physical hazard	1	1	2	Rescuer died two weeks later
#6	6/7/85	"Spent" acid storage tank	Toxic atmosphere	0	1	1	Rescuer was father of worker
#7	7/2/85	Underground waterline, valve area	Toxic atmosphere	1	0	1	Worker died of acute liver failure; another worker ill but recovered
#8	7/5/85	Sewage pumping station	Physical hazard; toxic atmosphere	1	3	4	2 died of drowning; 2 of asphyxiation
TOTALS				6	10	16	53 others injured

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Confined Spaces

Based on the information derived from these case studies, NIOSH concludes that these fatalities occurred as a result of encountering one or more of the following potential hazards:

- o lack of natural ventilation,
- o oxygen deficient atmosphere,
- o flammable/explosive atmosphere,
- o unexpected release of hazardous energy,
- o limited entry and exit,
- o dangerous concentrations of air contaminants,
- o physical barriers or limitations to movement, or
- o instability of stored product.

In each of these cases there was a lack of **RECOGNITION** and **TESTING**, **EVALUATION**, and **MONITORING** prior to entry nor had a well-planned **RESCUE** been attempted.

These incident reports suggest that **RECOGNITION** of what is a confined space in conjunction with the proper **TESTING**, **EVALUATION**, and **MONITORING** of the atmosphere and development of appropriate **RESCUE** procedures could prevent such deaths. These three steps are discussed below.

NIOSH investigations indicate that workers usually do not **RECOGNIZE** that they are working in a confined space and that they may encounter unforeseen hazards. **TESTING** and **EVALUATION** of the atmosphere are typically not initiated prior to entry and **MONITORING** is not performed during the confined space work procedures. **RESCUE** is seldom planned and usually consists of spontaneous reaction in an emergency situation.

#### **RECOMMENDATIONS**

In light of findings to date regarding occupational deaths in confined spaces, NIOSH recommends that managers, supervisors, and workers be made familiar with the following three steps:

##### **1. RECOGNITION**

Worker training is essential to the **RECOGNITION** of what constitutes a confined space and the hazards that may be encountered in them. This training should stress that death to the worker is the likely outcome if proper precautions are not taken before entry is made.

## 2. TESTING, EVALUATION, AND MONITORING

All confined spaces should be **TESTED** by a qualified person before entry to determine whether the confined space atmosphere is safe for entry. Tests should be made for oxygen level, flammability, and known or suspected toxic substances. **EVALUATION** of the confined space should consider the following:

- o methods for isolating the space by mechanical or electrical means (i.e., double block and bleed, lockout, etc.),
- o the institution of lockout-tagout procedures,
- o ventilation of the space,
- o cleaning and/or purging,
- o work procedures, including use of safety lines attached to the person working in the confined space and its use by a standby person if trouble develops,
- o personal protective equipment required (clothing, respirator, boots, etc.),
- o special tools required, and
- o communications system to be used.

The confined space should be continuously **MONITORED** to determine whether the atmosphere has changed due to the work being performed.

## 3. RESCUE

**RESCUE** procedures should be established before entry and should be specific for each type of confined space. A standby person should be assigned for each entry where warranted. The standby person should be equipped with rescue equipment including a safety line attached to the worker in the confined space, self-contained breathing apparatus, protective clothing, boots, etc. The standby person should use this attached safety line to help rescue the worker. The rescue procedures should be practiced frequently enough to provide a level of proficiency that eliminates life-threatening rescue attempts and ensures an efficient and calm response to any emergency.

## OTHER HELPFUL PUBLICATIONS BY NIOSH

NIOSH has published the following documents which contain further information:

Criteria for a Recommended Standard....Working in Confined Spaces, DHEW Publication No. 80-106.

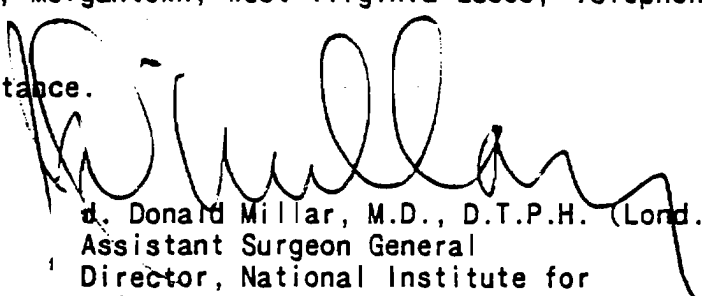
Page 9 - Request for Assistance in Preventing Occupational Fatalities in  
Confined Spaces

Guidelines for Controlling Hazardous Energy During Maintenance and  
Servicing, DHHS Publication No. 83-125.

We ask that editors of appropriate trade journals and safety and health  
officials (i.e., inspectors, managers, and hygienists, especially those  
associated with work in confined spaces) bring these recommendations to the  
attention of workers, supervisors, managers, and owners.

Requests for additional information on control practices or questions  
related to this announcement should be directed to Mr. John Moran, Director,  
Division of Safety Research, National Institute for Occupational Safety and  
Health, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505, Telephone  
(304) 291-4595.

We greatly appreciate your assistance.



J. Donald Millar, M.D., D.T.P.H. (Lond.)  
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Centers for Disease Control

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*Request for Assistance in*

**Preventing Fatalities of Workers  
Who Contact Electrical Energy**

*December 1986*

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
Public Health Service  
Centers for Disease Control  
National Institute for Occupational Safety and Health

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**REQUEST FOR ASSISTANCE IN PREVENTING FATALITIES  
OF WORKERS WHO CONTACT ELECTRICAL ENERGY**

**ATTENTION!**

**PROMPT EMERGENCY MEDICAL CARE CAN BE LIFESAVING FOR WORKERS WHO HAVE CONTACTED EITHER LOW VOLTAGE OR HIGH VOLTAGE ELECTRICAL ENERGY. IMMEDIATE CARDIOPULMONARY RESUSCITATION (CPR) FOLLOWED BY ADVANCED CARDIAC LIFE SUPPORT (ACLS) HAS BEEN SHOWN TO SAVE LIVES.**

**SUMMARY**

Recent incidents that have come to the attention of NIOSH have shown that electrocution victims can be revived if immediate cardiopulmonary resuscitation (CPR) or defibrillation is provided. While immediate defibrillation would be ideal, CPR given within approximately 4 minutes of the electrocution, followed by advanced cardiac life support (ACLS) measures within approximately 8 minutes, can be lifesaving. This alert describes recommendations that can be used to help save the lives of workers who contact electrical energy. Editors of appropriate trade journals, safety and health officials, and especially those who work with electrical equipment, are requested to bring these recommendations to the attention of owners, managers, and workers.

December 1986

## **BACKGROUND**

It has been estimated that at least 700 occupational electrocutions occur each year [1]. Therefore, a primary goal of occupational safety programs must be to prevent workers from contacting electrical energy. Effective measures include safe work practices, job training, proper tools, protective equipment, and lockout/tag-out procedures.

Investigations by NIOSH, as part of its Fatal Accident Circumstances and Epidemiology (FACE) Project, also have revealed that once an electrical energy incident occurs, emergency response plans are often lacking, even in organizations which promote safety. Hence, a secondary goal of safety programs must be to provide appropriate emergency medical care to workers who contact electrical energy.

The National Electrical Code divides voltages into two categories: greater than 600 volts (high voltage) and less than or equal to 600 volts (low voltage) [2]. Momentary contact with low voltages produces no thermal injury, but may cause ventricular fibrillation (very rapid, ineffective, heartbeat) [3].

In contacts with high voltage, massive current flows may stop the heart completely. When the circuit breaks, the heart may start beating normally [3]. Supporting respiration by immediate mouth-to-mouth techniques may be required, even if heartbeat and pulse are present. If extensive burns are present, death may result from subsequent complications [4].

## **APPROPRIATE STANDARDS AND GUIDELINES**

The revised "Standards and Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiac Care (ECC)" published in June 1986, is a product of the 1985 National Conference on CPR and ECC. There are two parts: basic cardiopulmonary resuscitation (CPR) and advanced cardiac life support (ACLS). A lay person can be trained in CPR to support circulation and ventilation of the victim of cardiac or respiratory arrest, until ACLS (provided by medical professionals using special equipment) can restore normal heart and ventilatory action [5].

Speed has been found to be critical to resuscitation: immediate defibrillation would be ideal. The highest success rate has been achieved in those patients for whom CPR followed cardiac arrest within approximately 4 minutes, and ACLS was begun within approximately 8 minutes of the arrest [5]. CPR often must be initiated immediately by lay individuals at the scene of the incident. It should be noted that CPR skills can be gained in 4-hour courses similar to those taught by the American Heart Association or the American Red Cross.

## **NIOSH CASE REPORTS**

### **Case #1 - SUCCESSFUL RESUSCITATION**

A 30-year-old construction worker was working on a fire escape in a building being renovated. Another worker handed the victim a metal pipe, and he was holding it with both hands when it contacted a nearby high voltage line, completing a path-to-ground. The worker instantly collapsed from this contact with electrical energy. Approximately 4 minutes after he collapsed, the fire department rescue squad arrived and began CPR. Within 6 minutes, a paramedic unit was on the scene providing defibrillation and other ACLS measures. They were able to establish a heartbeat and pulse, but the individual continued to require respiratory support during transport to the hospital. He regained consciousness and was discharged within two weeks. He did have to return for further medical care for burns he received on his hands (current entrance) and buttocks (current exit) [6].

### **Case #2 - UNSUCCESSFUL RESUSCITATION**

An 18-year-old male restaurant worker contacted electrical energy when he kneeled to plug a portable electric toaster into a 110-120 V/20 amp floor outlet. After a scream was heard, the victim was found convulsing on the damp floor, with one hand on the plug and the other on the receptacle box. The assistant manager went to the electrical panel, but was unable to locate the appropriate circuit breaker. A coworker attempting to take the victim's pulse received an electrical shock, but was not injured. After telephoning the emergency medical service, the assistant manager returned to the panel and de-energized all of the circuits (3 to 8 minutes after the worker contacted electrical energy). The injured worker was covered with a coat to "keep him warm." After about 5 minutes, another call was placed to the emergency squad, and the assistant manager "yelled" for an off-duty employee who lived in an apartment across the lot, who came and began CPR. The emergency service was on the scene 10 minutes after receiving the first call. ACLS measures were available, but the resuscitation was unsuccessful and the worker was pronounced "dead on arrival" at the local hospital. The exact time span between the worker contacting electrical energy and the beginning of CPR is unknown, but it is reasonable to assume that it was longer than 4 to 6 minutes. Paramedics with ACLS capability arrived 10 minutes after receiving the call, but more than 10 minutes after the accident occurred [7].

## **CONCLUSIONS**

In Case #1, basic life support was begun within 4 minutes by the fire department rescue squad who happened to be stationed nearby. They were experienced and had up-to-date knowledge in CPR techniques. In

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Who Contact Electrical Energy

this case, CPR was begun within the 4-minute recommendation. An ambulance, equipped and staffed to provide ACLS, arrived within 6 minutes. The standards and guidelines [5] for CPR within 4 minutes, and ACLS within 8 minutes, were met and the worker did survive.

In Case #2, the worker's contact with electrical energy was prolonged and a coworker who aided him received an electrical shock, because coworkers did not know how to de-energize the circuit. The optimal times for CPR and ACLS were exceeded, and the resuscitation was unsuccessful. Providing appropriate medical care after an electrical energy incident will not guarantee success. However, as has been reported elsewhere [5] and supported in the NIOSH case reports, the chance for successful resuscitation after cardiopulmonary arrest is best when the criteria for providing emergency medical care are met.

## **RECOMMENDATIONS**

### **1. PREVENTION**

**PREVENTION** must be the primary goal of any occupational safety program. However, since contact with electrical energy occurs even in facilities which promote safety, safety programs should provide for an appropriate emergency medical response.

### **2. SAFE WORK PRACTICES**

No one who works with electrical energy should work alone, and in many instances, a "buddy system" should be established. It may be advisable to have both members of the buddy system trained in CPR, as one cannot predict which will contact electrical energy.

Every individual who works with or around electrical energy should be familiar with emergency procedures. This should include knowing how to de-energize the electrical system before rescuing or beginning resuscitation on a worker who remains in contact with an electrical energy source.

All workers exposed to electrical hazards should be made aware that even "low" voltage circuits can be fatal, and that prompt emergency medical care can be lifesaving.

### **3. CPR AND ACLS PROCEDURES**

**CARDIOPULMONARY RESUSCITATION (CPR)** and first aid should be immediately available at every worksite. This capability is necessary to provide prompt (within 4 minutes) care for victims of cardiac or respiratory arrest, from any cause.

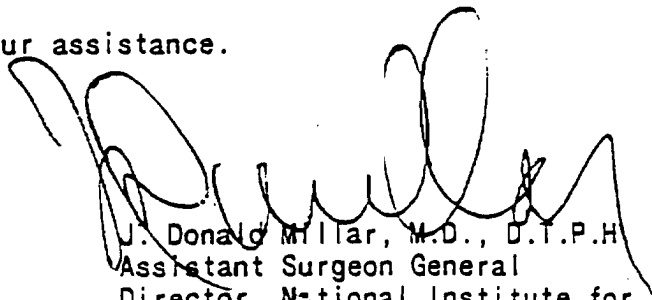
Page 5 - Request for Assistance in Preventing Fatalities of Workers  
Who Contact Electrical Energy

Employers may contact the local office of the American Heart Association, the American Red Cross, or equivalent groups or agencies, to set up a course for employees.

Provision should be worked out at each worksite to provide **ADVANCED CARDIAC LIFE SUPPORT (ACLS)** within 8 minutes (if possible), usually by calling an ambulance staffed by paramedics. Signs on or near phones should give the correct emergency number for the area, and workers should be educated regarding the information to give when the call is made. For large facilities, a prearranged place should be established for company personnel to meet paramedics in an emergency.

We are requesting that employers, worker representatives, editors of appropriate trade journals, and safety and health professionals assist in disseminating these recommendations to those individuals and organizations responsible for providing a safe workplace. Suggestions or questions related to this announcement should be directed to Mr. John Moran, Director, Division of Safety Research, National Institute for Occupational Safety and Health, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505-2888, telephone (304) 291-4595.

We greatly appreciate your assistance.



J. Donald Millar, M.D., D.T.P.H. (Lond.)  
Assistant Surgeon General  
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Occupational Safety and Health  
Centers for Disease Control

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DHHS (NIOSH) Publication No. 87-103

# NIOSH *ALERT*

JULY 1989

REQUEST FOR ASSISTANCE IN

## **Preventing Electrocutions of Workers Using Portable Metal Ladders Near Overhead Power Lines**

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
Public Health Service  
Centers for Disease Control  
National Institute for Occupational Safety and Health



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# NIOSH ALERT

## Request for Assistance In

## Preventing Electrocutions of Workers Using Portable Metal Ladders Near Overhead Power Lines

### WARNING!

**Persons using portable metal or conductive ladders near energized overhead power lines are at risk of electrocution.**

The National Institute for Occupational Safety and Health (NIOSH) is requesting assistance in preventing electrocutions that occur when portable metal ladders (including aluminum ladders) contact overhead power lines. Portable metal ladders are used widely in many industries. This *Alert* describes six deaths that occurred because portable aluminum ladders, which are electrical conductors, came in contact with energized overhead power lines. If nonconductive ladders had been used instead, or if safe working clearances had been maintained, these deaths might have been prevented.

Specific Occupational Safety and Health Administration (OSHA) regulations govern the use of portable metal ladders. These regulations should be implemented and enforced by every employer, manager, supervisor, and worker in operations that use portable metal ladders. Editors of appropriate trade journals, safety and health officials, and other persons (especially those in the building trades) are requested to bring the recommendations in this *Alert* to the attention of contractors and workers.

### BACKGROUND

Contact between portable metal ladders and overhead power lines causes serious and often fatal injuries to workers in the United States. Data show that during the years 1980 through 1985, the contact of metal ladders with overhead power lines accounted for approximately 4% of all work-related electrocutions in the United States (e.g., 17 out of 382 deaths for 1985) [NIOSH 1988].

### REGULATIONS

Safety regulations promulgated by the Occupational Safety and Health Administration (OSHA) establish specific requirements intended to prevent workers from positioning portable metal ladders where they might contact electrical conductors [29 CFR\* 1926.450(a)(11) and 1926.951(c)(1)]. These regulations stipulate that "portable metal or conductive ladders shall not be used for electrical work or where they may contact

\*Code of Federal Regulations. See CFR in references.

electrical conductors." Other pertinent regulations require that "portable ladders in use shall be tied, blocked, or otherwise secured to prevent their being displaced" [29 CFR 1926.450(a)(10)]. Additional OSHA regulations require employers to instruct each worker to recognize and avoid unsafe conditions [29 CFR 1926.21(b)(2)], and to provide prompt medical attention in case of serious injury [29 CFR 1926.50].

## **CASE REPORTS**

As part of the Fatal Accident Circumstances and Epidemiology (FACE) Program, NIOSH investigated five incidents (resulting in six electrocutions) that occurred between 1985 and 1987 and that involved contact between portable aluminum ladders and overhead power lines.

### **Case No. 1 - One Fatality**

On May 4, 1985, a 28-year-old male worker removed the bottom of a poster on a 12-by-24-foot (-ft) billboard that was scheduled for reposting. He then removed a 24-ft aluminum hook ladder from the service truck. While the worker was positioning the ladder to reach the top section of the billboard, the ladder contacted a 7,200-volt (-V) overhead power line that was located 8 ft from the top of the billboard, and he was electrocuted [NIOSH 1985a].

### **Case No. 2 - One Fatality**

On July 21, 1986, a 27-year-old male painter was standing on a fully extended 24-ft aluminum ladder while painting a rain gutter on an apartment building. After painting a section of the gutter, the worker descended the ladder to move it to a new location. As he was repositioning the ladder, it contacted a 7,200-V overhead power line that was located 8 ft from the gutter, and he was electrocuted [NIOSH 1987d].

### **Case No. 3 - Two Fatalities**

On November 17, 1986, two male painters (20 and 21 years old) were using a 36-ft aluminum extension ladder to paint a 20-ft-high metal

light pole. One worker was standing on the ladder painting, and his coworker was on the ground holding the ladder. The ladder slipped away from the pole and contacted a 12,460-V overhead power line that was located within 2 ft of the pole. Both painters were electrocuted [NIOSH 1987c].

### **Case No. 4 - One Fatality**

On September 1, 1987, a 28-year-old male painter and a coworker were using an aluminum extension ladder while cleaning the outside brick wall of a three-story convalescent home before painting. After cleaning one section, the workers moved the ladder to another location. The painter held the base of the ladder as the coworker simultaneously climbed and raised the extension of the 40-ft ladder. When the ladder was extended to approximately 34 ft, it tipped backward, contacting a 7,200-V overhead power line that was located 15 ft from the structure. The coworker on the ladder received an electrical shock and fell to the ground. The painter holding the ladder provided a path to the ground for the electrical current and was electrocuted [NIOSH 1987b].

### **Case No. 5 - One Fatality**

On September 24, 1987, an 18-year-old male construction worker and two coworkers were looking for an area on an office building roof to store shingles. The 18-year-old and a coworker were holding a fully extended, 32-ft aluminum ladder as the other coworker descended it. The ladder tipped backward, contacting a 7,200-V overhead power line that was located 6 ft from the building, electrocuting the 18-year-old worker holding the ladder, and shocking the other two coworkers [NIOSH 1987a].

## **APPLICATION OF EXISTING REGULATIONS**

Data demonstrated that employers and workers in all five fatal incidents violated the following applicable\* OSHA regulations:

\*Regulation No. 3 did not apply to Case No. 1.

1. Portable metal or conductive ladders shall not be used for electrical work or where they may contact electrical conductors [29 CFR 1926.450(a)(11) or 1926.951(c)(1)].
2. Employers shall instruct each employee in the recognition and avoidance of unsafe conditions and the regulations applicable to his work environment to control or eliminate any hazards or other exposure to illness or injury [29 CFR 1926.21(b)(2)].
3. Portable ladders in use shall be tied, blocked, or otherwise secured to prevent their being displaced [29 CFR 1926.450(a)(10)].

Compliance with these regulations might have prevented all five deaths.

## CONCLUSIONS

The principal objectives of the NIOSH FACE Program are to identify potential risk factors that may contribute to traumatic worker deaths and to recommend measures that might prevent similar fatalities. Whether or not a work operation complies with existing OSHA regulations is only one variable that may contribute to a fatality. However, in the investigations reported here, full compliance with relevant OSHA regulations would probably have prevented these deaths. The lack of compliance with existing regulations in the five incidents described suggests that many employers and workers may be (1) working unaware of these OSHA regulations, (2) misinterpreting the requirements of the regulations, or (3) failing to inform their workers about the dangers of using metal ladders around overhead power lines.

## RECOMMENDATIONS

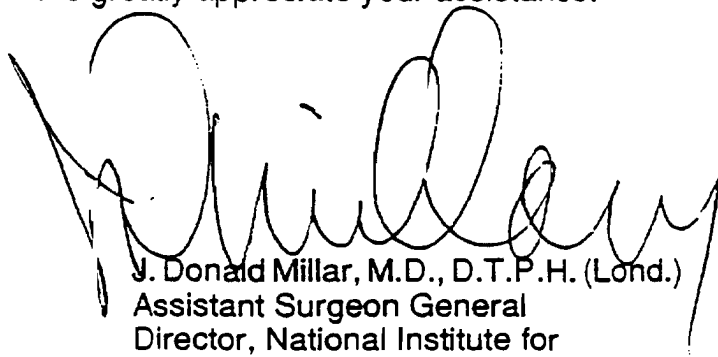
The following recommendations will help prevent deaths and injuries resulting from contact between metal ladders and overhead power lines:

- NIOSH recommends that employers and workers comply with the OSHA regulation prohibiting the use of portable metal or conductive ladders for electrical work or in locations where they may contact electrical conductors. Nonconductive ladders such as those made of wood or fiber glass should be used instead.
- Employers should fully inform workers about the hazards of using portable metal (including aluminum) ladders near energized power lines.
- If portable metal ladders are used in the vicinity of energized power lines, NIOSH urges that all employers and workers strictly adhere to the OSHA safety regulations [29 CFR 1926.450 and 1926.951(c)(1)] for providing proper balancing and securing of ladders, and for maintaining safe working distances to avoid contact with electrical conductors.
- To assure proper protection for anyone working near electrical power lines, arrangements should be made with the power company to de-energize the lines or to cover the lines with insulating line hoses or blankets.
- Employers should provide workers with training in emergency medical procedures such as cardiopulmonary resuscitation. Fatalities may be prevented by prompt emergency medical care.

NIOSH also urges safety and trade associations, electrical utility companies, product manufacturers, and OSHA State consultative services to bring these recommendations to the attention of employers and workers using portable metal ladders. Further information on electrical energy hazards can be found in six previously published NIOSH *Alerts* [NIOSH 1987e, NIOSH 1986a, NIOSH 1986b, NIOSH 1986c, NIOSH 1985b, NIOSH 1984].

Suggestions, requests for additional information on safe work practices, or questions related to this announcement should be directed to Dr. Thomas R. Bender, Director, Division of Safety Research, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505-2888; telephone (304) 291-4595.

We greatly appreciate your assistance.



J. Donald Millar, M.D., D.T.P.H. (Lond.)  
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Centers for Disease Control

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# NIOSH

# ALERT

December 1989

REQUEST FOR ASSISTANCE IN

## **Preventing Worker Deaths and Injuries from Falls Through Skylights and Roof Openings**

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
Public Health Service  
Centers for Disease Control  
National Institute for Occupational Safety and Health



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DHHS (NIOSH) Publication No. 90-100

# NIOSH ALERT

## Request for Assistance in

## Preventing Worker Deaths and Injuries from Falls Through Skylights and Roof Openings

### WARNING!

**Fatal falls may result from failure to provide appropriate guarding and fall protection for work around skylights, skylight openings, and other roof openings.**

The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing deaths from work near skylights, skylight openings, and other types of roof openings. Recent investigations by NIOSH suggest that many fatal falls involve such openings. This *Alert* describes eight deaths resulting from falls that occurred during work around these openings.

Existing standards of the Occupational Safety and Health Administration (OSHA) regulate the guarding of skylights and other roof openings. Every employer, supervisor, and worker in companies where the work may involve exposure to these hazards should comply with these standards. NIOSH requests editors of appropriate trade journals, safety and health officials, and employers in the construction trades to bring the recommendations in this *Alert* to the attention of contractors and workers.

### BACKGROUND

Occupational fatalities caused by falls remain a serious public health problem throughout the United States. The U.S. Department of Labor lists falls as one of the leading causes of traumatic occupational death, accounting for 8% of all occupational fatalities from trauma (approximately 289 of 3,610 deaths) in 1986 [BLS 1988]. The NIOSH National Traumatic Occupational Fatality (NTOF) data base indicates that during the period 1980-85, falls accounted for nearly 10% (3,491 of 36,210) of all traumatic occupational deaths for which a cause was identified [NIOSH 1989a]. Of this total, 28 deaths resulted from falls through skylights, and 39 deaths resulted from falls through roofs or roof openings. A NIOSH survey in seven States revealed that approximately 22% (14 of 64) of the fatal falls reported to State occupational safety and health officials occurred when workers fell through skylight openings or smoke-vent

skylights (translucent plastic domes that serve as both skylights and automatic smoke vents in case of fire). The recent increase in the use of smoke-vent skylights in new construction has increased the exposure of workers to these hazards. Deaths can be prevented by compliance with existing OSHA standards for guarding roof openings and by improvement in the worker's awareness of the hazards involved in working near skylights, skylight openings, and other roof openings.

## RELEVANT REGULATIONS

OSHA has promulgated regulations to protect workers from the hazards associated with roof openings [29 CFR\* 1910 and 1926]. The OSHA General Industry Standard requires that "every skylight floor opening and hole shall be guarded by a standard skylight screen or a fixed standard railing on all exposed sides" [29 CFR 1910.23(a)(4)]. Requirements for a standard skylight screen are given in 29 CFR 1910.23(e)(8), as follows:

Skylight screens shall be of such construction and mounting that they are capable of withstanding a load of at least 200 pounds applied perpendicularly at any one area on the screen. They shall also be of such construction and mounting that under ordinary loads or impacts, they will not deflect downward sufficiently to break the glass below them. The construction shall be of grillwork with openings not more than 4 inches long or of slatwork with openings not more than 2 inches wide with length unrestricted.

The OSHA Construction Standard addresses the hazards posed by skylight openings during construction:

Wherever there is a danger of falling through a skylight opening, it shall be guarded by a fixed standard railing on all exposed sides or a cover capable of sustaining the weight of a 200 pound person [29 CFR 1926.500(b)(4)].

\*Code of Federal Regulations.

## CASE REPORTS

The following case reports demonstrate that employers and workers violated the applicable OSHA regulations in all eight fatal incidents. Compliance with these regulations might have prevented all eight deaths.

From October 1987 through April 1989, NIOSH, as a part of the Fatal Accident Circumstances and Epidemiology (FACE) Program, has investigated five fatal falls involving skylights or roof openings. These incidents are reported here along with information from three similar cases (Case Nos. 6, 7, and 8) previously investigated by the State of Maryland.

### Case No. 1 - One Death

On October 30, 1987, a 24-year-old male plumber died when he fell through an unguarded skylight opening to a concrete floor approximately 22 feet below. The victim and a coworker were installing plumbing fixtures on the roof of a new building. The roof contained numerous 4- by 4-foot openings framed with 2- by 6-inch wood. These openings were intended for smoke-vent skylights when the structure was complete. Although the victim and others had been working on this project for several days before the incident, no fall protection or guards of any type were in place. At the time of the incident, the victim and a coworker were discussing the relocation of a fixture on the roof. The victim was walking away from his coworker and looking back over his shoulder to talk to him when he stepped through a skylight opening [NIOSH 1988a].

### Case No. 2 - One Death

On January 6, 1988, an 18-year-old male sheet metal helper died after he fell through a

skylight opening to a concrete floor 33 feet below. The victim was working as a member of a crew engaged in replacing corrugated metal roof sheeting and installing chain-link fencing material on top of 3- by 8-foot fiber glass panels used as skylights. The fencing material was being installed to eliminate the hazard of falls posed by the fiber glass skylights. (Three months earlier a worker on the same site had fallen to his death through one of these skylights.) When the supervisor ordered the crew to stop work temporarily, the members of the crew moved toward a vent stack to warm themselves. As they moved, the victim stepped on one of the unguarded skylights and fell through it. He died at the hospital 2 hours later [NIOSH 1988b].

#### **Case No. 3 - One Death**

On December 14, 1988, a 41-year-old male ironworker died after he fell 25 feet through a roof opening. The victim was working as a member of an eight-man crew installing steel decking on the roof of a new six-story building. The victim left the work area to get a small piece of decking material to finish the job. When the victim did not return in 5 minutes, the crew searched for him and found him lying unconscious on the fifth floor of the stairwell. The victim had removed a 3- by 6-foot piece of decking that covered a 2-foot-square ventilation opening in the top of the stairwell; apparently, he then stepped forward and fell through the opening. The victim died 12 hours later as a result of his injuries [NIOSH 1989b].

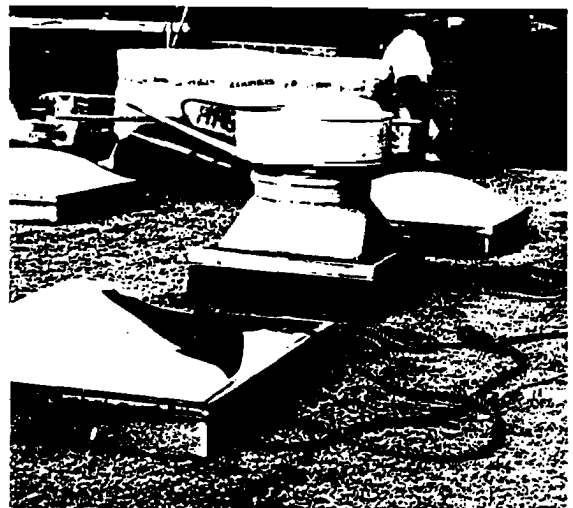
#### **Case No. 4 - One Death**

On December 20, 1988, a 26-year-old male sheet metal mechanic died when he was knocked through a roof opening and fell to a concrete floor 22 feet below. The victim and

one coworker were preparing to install a 75-pound, 54-inch-square steel cap over a 50-inch-square opening on the roof of a manufacturing plant. The men placed the cap so that it leaned against a metal structure on the roof 34 inches from the edge of the roof opening. The victim then moved between the cap and the roof opening and stooped over to apply caulking to the 6-inch raised curb of the opening. A gust of wind dislodged the cap, which struck the victim and knocked him headfirst through the roof opening [NIOSH 1989c].

#### **Case No. 5 - One Death**

On April 18, 1989, a 39-year-old male electrician's helper died when he fell through a domed, smoke-vent skylight (see Figure 1) to a concrete floor 16 feet below. Using a 1-inch-diameter rope, the victim and one coworker had lowered an old electric sign to the ground from the side of an unoccupied single-story building. The victim stayed on the roof to coil the rope while the coworker went



**Figure 1.** Scene of a skylight accident where a worker fell to his death (Case No. 5).

to load the sign onto a truck. Approximately 7 minutes after leaving the victim on the roof, the coworker entered the building and observed the victim lying on the concrete floor beneath a shattered skylight. Apparently the victim either sat on or fell into the skylight, which collapsed under his weight [NIOSH 1989d]. The victim suffered massive head injuries and was pronounced dead at the scene.

#### **Case No. 6 - One Death**

On May 12, 1986, a 21-year-old male laborer died when he fell through a domed, smoke-vent skylight to a concrete floor 27 feet below. The victim had been throwing old roofing materials off a roof with six unguarded skylights. During a work break, the victim sat down on one of the skylights, which began to break under his weight. As he attempted to raise himself from the skylight with his arms, the plastic dome failed completely and he fell. Officials from the State of Maryland Occupational Safety and Health Administration reported that the victim had been warned by his supervisor and coworkers not to sit on skylights [MOSH 1986].

#### **Case No. 7 - One Death**

On July 30, 1986, a 37-year-old male roofer died after he stepped through a partially covered skylight opening and fell 27 feet below. Along with seven other workers, the victim was installing rolled rubber roofing material on a large building. The roof contained 35 unguarded 4- by 4-foot openings where domed smoke-vent skylights were to be installed. While handling a roll of roofing material, the victim stepped back and fell through an opening that had been partially covered by another roll of roofing material. He died the following day [MOSH 1987a].

#### **Case No. 8 - One Death**

On March 6, 1987, a 26-year-old male roofer died when he fell through a domed smoke-vent skylight to a concrete floor 25 feet below. The victim and two coworkers were installing a spray-on roof covering. The two coworkers were applying sealant, and the victim was applying granular material. As the victim stepped back, he stumbled over the curb of a skylight, lost his balance, and fell backward onto the skylight. The plastic dome fractured under his weight, and he fell to his death [MOSH 1987b].

### **CONCLUSIONS**

Although current OSHA standards require employees to guard both skylights and roof openings, these standards were being violated in each case reviewed in this *Alert*. Employers and workers may believe that the translucent plastic domes on smoke-vent skylights provide an adequate barrier against falls, but many domes do not [ENR 1989]. Based on the incidents reported here, NIOSH concludes that the increased use of skylights in new construction presents a serious hazard to workers in the construction trades.

### **RECOMMENDATIONS**

NIOSH recommends that the following precautions be taken to prevent fatal falls through skylights, skylight openings, and other roof openings:

- NIOSH urges that all employers and workers strictly adhere to the applicable OSHA regulations.

—Railings or screens guarding all skylights and other openings in roofs

must be installed *before* roofing work begins and must remain in place until construction is completed, in accordance with 29 CFR 1910.23 and 1926.500.

—As required by current OSHA standards [29 CFR 1926.28(a)] and consistent with accepted safe work practices, employers must provide protection against falls before workers begin any operations that include the potential for serious falls.

—Where conventional protective devices such as guardrails or safety belts/harnesses with lanyards may not be practical, employers must provide alternative forms of protection against falls such as fixed covers, catch platforms, or safety nets as described in 29 CFR 1926.105. *All of the construction-related fatalities described here could have been prevented had appropriate safety netting been securely in place directly below the roof openings.* Nets are especially useful because they provide passive protection for workers—that is, the protection does not depend on workers to recognize the hazard and take appropriate protective action. In construction operations, netting can be installed when the roof openings are made and left in place until all construction activities are complete or until more permanent guards are installed.

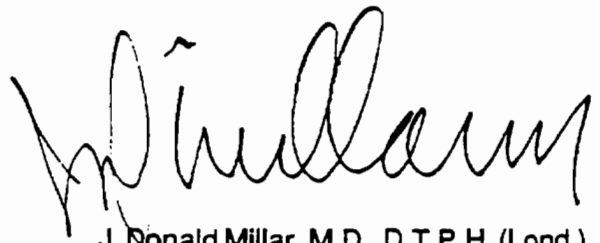
- Employers should assure that all workers required to work near roof openings or skylights are adequately trained to recognize the serious hazard of falls (even from relatively low heights) through roof openings, and the danger of sitting or stepping on skylights.

- Manufacturers or purchasers of skylights should affix conspicuous decals to each skylight, warning individuals against sitting or stepping on these units.

- Manufacturers should modify the design of skylights to strengthen them sufficiently to support the weight of a worker who steps, sits, or falls on one. If such changes would adversely affect the smoke-venting capacity of the skylight, a dome-shaped protective grillwork over the skylight should be considered.

Comments or questions concerning this *Alert* should be directed to Dr. Thomas R. Bender, Director, Division of Safety Research, National Institute for Occupational Safety and Health, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505-2888; telephone (304) 291-4595.

We greatly appreciate your assistance, which is crucial to protecting the lives of American workers.



J. Donald Millar, M.D., D.T.P.H. (Lond.)  
Assistant Surgeon General  
Director, National Institute for  
Occupational Safety and Health  
Centers for Disease Control

## REFERENCES

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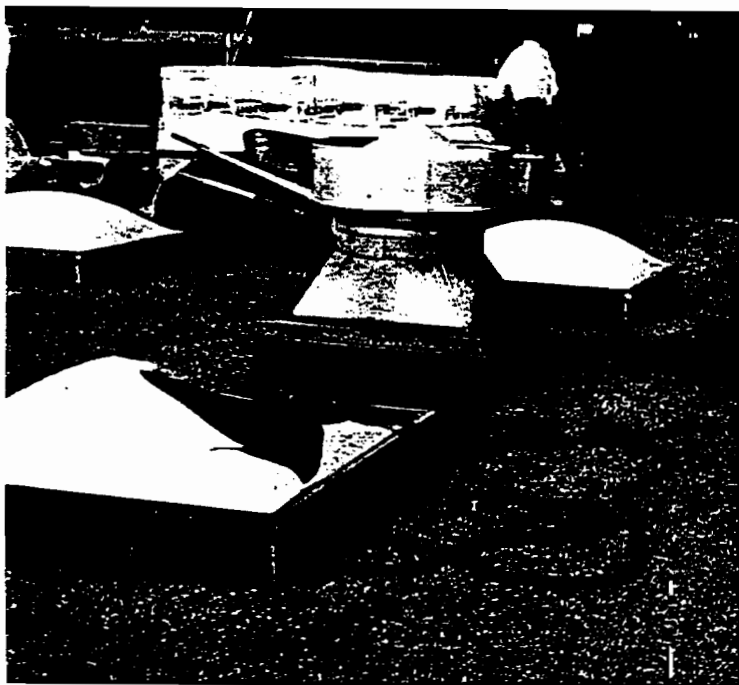
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# NIOSH ALERT



**Warning!**

**Many workers have died from falls through skylights or roof openings.**

1. Be aware of all skylights and roof openings in your work area.
2. Do not sit or step on skylights—they may not support your weight.
3. Read any safety decals affixed to skylights.
4. Use fall protection for *any* work that might result in falls.
5. Make sure that all skylights and roof openings are appropriately guarded *before* work begins.
6. Use nets, catch platforms, or fixed covers if guardrails, screens, protective grillwork, and safety belts are not practical.

For additional information, refer to the NIOSH Alert on Skylights (DHHS NIOSH 90-100), or call 1-800-35-NIOSH.

U.S. Department of Health and Human Services  
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# NIOSH ALERT

August 1991

REQUEST FOR ASSISTANCE IN

## Preventing Electrocutions During Work with Scaffolds Near Overhead Power Lines



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
Public Health Service  
Centers for Disease Control  
National Institute for Occupational Safety and Health

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DHHS (NIOSH) Publication No. 91-110

# **NIOSH ALERT**



**Request for Assistance In**

## **Preventing Electrocutions During Work with Scaffolds Near Overhead Power Lines**

### **WARNING!**

**Workers may be electrocuted when erecting, moving, or working from metal or conductive scaffolds near overhead power lines.**

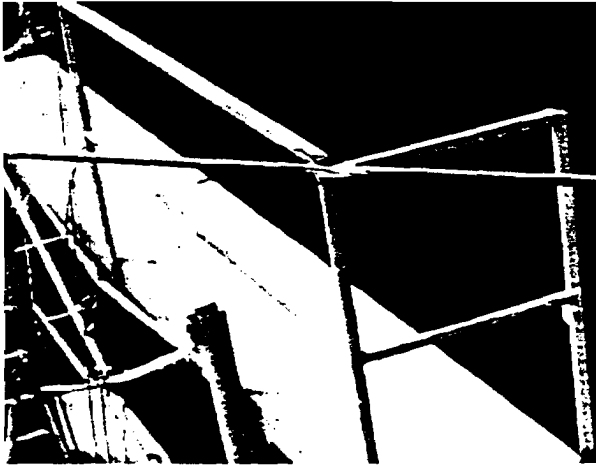
The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing electrocutions of workers who contact overhead power lines when erecting or moving scaffolds, or when using conductive tools or materials from scaffolds. Recent NIOSH investigations conducted under the Fatal Accident Circumstances and Epidemiology (FACE) Program suggest that many employers, contractors, and workers may be unaware of the hazards of working with scaffolds near uninsulated overhead power lines.

This Alert describes 13 deaths that occurred in six separate incidents when workers erected or moved scaffolds that came into contact with energized, overhead power lines, or when they contacted overhead power lines while using conductive tools or materials from scaffolds. To prevent such electrocutions, the recommendations in this Alert should be followed by every employer, manager, supervisor, and worker where scaffolds

and conductive tools or materials are used near overhead power lines. Editors of appropriate trade journals, safety and health officials, and other persons (especially those in the building trades) are requested to bring this Alert to the attention of employers, contractors, and workers.

### **BACKGROUND**

When scaffolds, conductive tools, or other materials contact overhead power lines (see Figure 1), workers receive serious and often fatal injuries. Data from the NIOSH National Traumatic Occupational Fatalities (NTOF) data base indicate that nearly 6,500 traumatic work-related deaths occur each year in the United States; an estimated 7% of these fatalities are electrocutions [NIOSH 1991]. The NTOF data base also shows that from 1980 through 1986, at least 25 deaths resulted when workers contacted overhead power lines while erecting or moving scaffolds or while using conductive tools on scaffolds.



**Figure 1.** Metal scaffold contacting an overhead power line.

A review of the NTOF data has revealed that many occupational groups (e.g., brick-masons, carpenters, painters, construction laborers, and plasterers) are at risk of electrocution because their jobs involve working from scaffolds near overhead power lines [NIOSH 1991]. Through the FACE program, NIOSH investigated 13 scaffold-related electrocutions occurring over a 39-month period (June 1986 through September 1989). Because the FACE program is active in only 11 states, these fatalities represent only a small proportion of the scaffold-related electrocutions that occur each year in the United States.

### **CURRENT OSHA REGULATIONS**

Current Occupational Safety and Health Administration (OSHA) regulations for the construction industry require employers to do the following:

- Instruct each worker to recognize and avoid unsafe conditions [29 CFR\* 1926.21(b)(2)]

\*Code of Federal Regulations. See CFR in references.

- Provide prompt medical attention in case of serious injury [29 CFR 1926.50]
- Advise workers exposed to electrical hazards and protect against electric shock by de-energizing the circuit or by guarding it effectively with insulation or other means [29 CFR 1926.416(a)(1) and (a)(3)]
- Post warning signs where such electrical hazards exist [29 CFR 1926.416(a)(3)]
- Lock panels (scaffold sections or tiers) together vertically with pins or other equivalent means where uplift (separation of panels) may occur [29 CFR 1926.451(d)(6)]

OSHA has proposed revisions to the current safety regulations to prevent workers from placing scaffolds where they might contact overhead power lines or other energized circuits [51 Fed. Reg. 42706 (1986)]. These proposed regulations require that the following minimum clearances be maintained between scaffolds and exposed, energized power lines:

- 2 feet for insulated power lines of less than 300 volts
- 10 feet for insulated power lines of 300 volts or more and for all uninsulated power lines

### **CASE REPORTS**

As part of the FACE Program, NIOSH investigated 13 electrocutions in six incidents that occurred between June 1986 and September 1989. Each incident involved electrical contact with conductive tools or materials used by workers on scaffolds, or workers who erected or moved scaffolds near overhead power lines.

#### **Case No. 1 – Two Fatalities**

On June 17, 1986, a 28-year-old painter and a 33-year-old carpenter were painting church windows from a tubular, welded-frame scaffold approximately 25 feet high and mounted on rubber casters. After the workers had completed one side of the church, they attempted to move the scaffold to another location to continue painting. The workers passed the scaffold under a 12,000-volt power line that was approximately 30 feet above ground level. They then changed direction and tried to pass the scaffold under the same power line at a point that was only 24 feet above ground level. The scaffold contacted one phase of the power line, providing a path to the ground for the electric current. The two workers grasping the scaffold were electrocuted [NIOSH 1986e].

#### **Case No. 2 – One Fatality**

On August 27, 1986, a company owner and six workers were painting a concrete silo. A 5- by 7-foot tubular, welded-frame scaffold was erected to reach the top of the silo approximately 6 feet across from a 7,200-volt power line. Workers were using 8-foot aluminum poles with rollers to paint the side of the silo. A 19-year-old laborer who was painting from the scaffold pulled the aluminum pole back onto the scaffold to load more paint onto the roller. In doing so, he contacted the power line with the aluminum pole and was electrocuted [NIOSH 1986g].

#### **Case No. 3 – Four Fatalities**

On October 31, 1986, a crew of four painters (aged 56, 37, 37, and 31) completed painting one side of a three-story structure. The crew was using a five-tier, tubular, welded-frame scaffold mounted on 5-inch, rubber-clad aluminum wheels. The painters and the crew chief attempted to move the 28.5-foot scaffold

to the other side of the structure. The scaffold contacted one phase of a 12,000-volt power line that was approximately 27.5 feet above the ground. The contact created a path to the ground for the electric current. The four painters were electrocuted and the crew chief was severely burned [NIOSH 1986a].

#### **Case No. 4 – One Fatality**

On November 24, 1986, seven employees of a masonry company were erecting a brick wall from a tubular, welded-frame scaffold approximately 24 feet high. The scaffold had been constructed approximately 21 inches across from a 7,620-volt power line. A laborer carried a piece of wire reinforcement (10 feet long by 8 inches wide) along the top section of the scaffold and contacted the power line with it. The laborer, who was wearing leather gloves, received an electric shock and dropped the wire reinforcement, which fell across the power line and simultaneously contacted the metal rail of the scaffold, energizing the entire scaffold. A 20-year-old bricklayer standing on the work platform in contact with the main scaffold was electrocuted [NIOSH 1986f].

#### **Case No. 5 – Two Fatalities**

On June 5, 1987, a seven-tier, tubular, welded-frame scaffold (31 feet high) was erected to paint a 33-foot-high sign at the entrance of a new shopping mall. After the sign had been partially painted, the scaffold was moved to allow concrete to be placed in the area around the sign. The scaffold was positioned approximately 10 feet horizontally from a 13,750-volt overhead power line. Several days later, the crew of seven workers (carpenters, laborers, and painters) were instructed to replace the scaffold and finish painting the sign. The crew positioned themselves around the scaffold and attempted to lift it approximately 5 inches onto the newly

constructed concrete pad. As they were lifting the scaffold, the top section partially separated from the adjoining section, toppled over, and contacted the power line. A 28-year-old carpenter and a 31-year-old laborer were electrocuted. The other five workers were hospitalized with electrical burns [NIOSH 1987b].

#### **Case No. 6 – Three Fatalities**

On September 25, 1989, six workers were using a mobile, elevated work platform to install aluminum siding on a warehouse under construction. The platform measured 25.5 feet from ground level to the top guardrail. Approximately 3 days before the incident, the crew had passed the platform under a 69,000-volt overhead power line located 34 feet above the ground. On the day of the incident, the crew tried to pass the platform under the same power line at a different location where the power line was only 27 feet above ground level. In addition, fill dirt brought into this location for landscaping caused the ground level to slope upward approximately 1.5 feet. As the crew passed the platform under the power line, the top guardrail contacted the bottom phase of the power line. Three crew members (a 30-year-old laborer and two steel workers aged 34 and 38) were electrocuted; three others were seriously burned [NIOSH 1990b].

#### **CONCLUSIONS**

Many employers, contractors, and workers may be unaware of the hazards of working with scaffolds near overhead power lines. If the current and the proposed OSHA regulations had been followed, particularly with regard to minimum clearances, the electrocutions reported here could have been prevented.

#### **RECOMMENDATIONS**

The following precautions should be taken to prevent electrocutions and injuries resulting from contact between overhead power lines and conductive tools, materials, or scaffolds:

- Employers, contractors, and workers should comply with the current OSHA regulations for working with scaffolds near energized power lines [29 CFR 1926.21(b)(2), 1926.50, 1926.416(a)(1), 1926.416(a)(3), 1926.451(d)(6)].
- In accordance with the proposed OSHA regulations [51 Fed. Reg. 42706 (1986)], scaffolds should not be used or moved within the following minimum clearance distances from exposed, energized power lines:
  - 2 feet for insulated power lines of less than 300 volts
  - 10 feet for insulated power lines of 300 volts or more and for all uninsulated power lines
- Employers should review existing safety programs and revise them where needed to address work with scaffolds around power lines.
- Employers should develop and implement safety programs where none exist. Comprehensive safety programs should include, but not be limited to, safety training in the hazards of scaffolds and power lines, with special emphasis on avoiding inadvertent contact.
- Managers and workers should conduct initial and daily surveys at the worksite before beginning any job; managers

should then implement appropriate control measures and training to address hazards identified at the site.

- Employers should inform workers about the hazards of erecting, moving, or working from scaffolds near overhead power lines or other energized circuits. These instructions should emphasize that most overhead, high-voltage power lines are *not insulated* and that workers should assume that such lines are not insulated if there is any doubt.
- Employers should notify the utility company when scaffolds must be erected or moved in areas with overhead power lines where the required clearances cannot be maintained. In such situations, utility companies should de-energize the power lines or cover them with insulating hoses or blankets before any work is initiated.
- Before a scaffold is erected or moved, employers should ensure that workers consider the following factors:
  - Distance from overhead power lines
  - Vertical clearance between the ground and any sagging power lines
  - Scaffold height and weight
  - Wheel condition
  - Obstacles
  - Ground slope or changes in elevation that may alter clearance distance
  - Other ground or floor conditions
- Clearance between the power lines and scaffold should be monitored. If a scaffold is to be moved in the vicinity of overhead power lines, a competent worker should be assigned to observe the clearance and

warn others if the minimum distance is not maintained.

- Electrically conductive tools or materials should not be used where they may contact overhead power lines. Nonconductive tools or materials should be substituted.
- Manufacturers should consider developing scaffolds made of nonconductive materials.
- Employers should establish procedures to be followed in emergencies (for example, if a scaffold contacts an electric power line, keep all unauthorized personnel away from the area).
- All employers and workers should be trained in cardiopulmonary resuscitation (CPR) [NIOSH 1986c, 1989a, 1989b, 1990a].
- Manufacturers or purchasers of scaffolds should affix conspicuous decals to each scaffold section warning about the hazards of contacting overhead power lines.

NIOSH urges safety and trade associations, electric utility companies, product manufacturers, and OSHA State consultative services to bring these recommendations to the attention of all employers and workers using scaffolds.

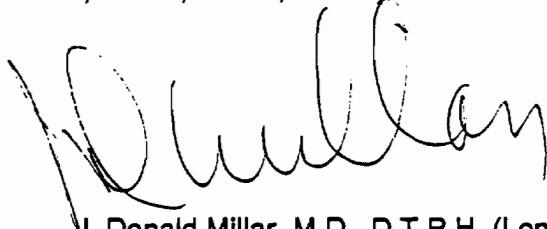
## ACKNOWLEDGMENTS

Richard W. Braddee, Division of Safety Research, NIOSH, was the principal author of this Alert.

Comments or questions about this document should be directed to Thomas R. Bender, M.D., Director, Division of Safety Research, National Institute for Occupational Safety and

Health, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505-2888; telephone (304) 291-4595.

Further information about electrical hazards is available in seven previously published NIOSH Alerts [NIOSH 1984, 1985, 1986b, 1986c, 1986d, 1987a, 1989a].



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Director, National Institute for  
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Centers for Disease Control

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# NIOSH ALERT

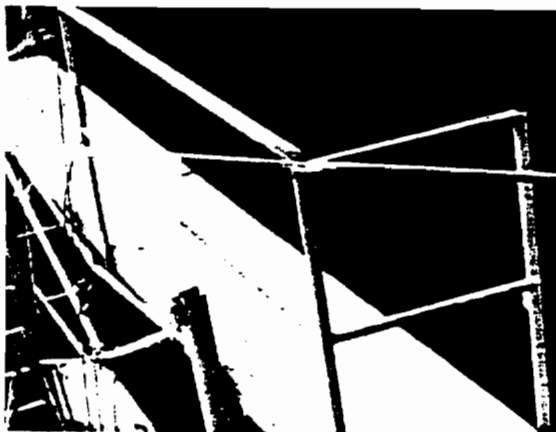
## Scaffolds Near Overhead Power Lines

### WARNING!

Workers may be electrocuted when erecting, moving, or working from metal or conductive scaffolds near overhead power lines.

Take the following actions to protect yourself if you are erecting, moving, or working from metal or conductive scaffolds near overhead power lines.

- Be aware of overhead power lines in your work area. Most overhead power lines are not insulated.
- Conduct initial and daily surveys of the worksite and implement control measures and training to address hazards at the site.
- Recognize the hazards of moving, erecting, or working from scaffolds near overhead power lines.
- Restrict the use of electrically conductive tools or materials where they may contact overhead power lines.
- Be trained in cardiopulmonary resuscitation (CPR).
- Always maintain the following minimum clearance between scaffolds and power lines:
  - 2 feet for insulated power lines of less than 300 volts
  - 10 feet for insulated power lines of 300 volts or more and for all uninsulated power lines
- If scaffolds must be moved in the area of overhead power lines, appoint a competent worker to observe the clearance between the power lines and the scaffold and warn others if the minimum distance is not maintained.
- If minimum clearance cannot be maintained when scaffolds must be erected or moved near overhead power lines, notify the utility company to de-energize the power lines or provide adequate insulation before any work is initiated.



Metal scaffold contacting an overhead power line.

For additional information, refer to the NIOSH Alert on Scaffolds Near Overhead Power Lines [DHHS (NIOSH) 91-110], or call 1-800-35-NIOSH. Single copies are available free from the following:

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# NIOSH ALERT

APRIL 1992

REQUEST FOR ASSISTANCE IN

## Preventing Lead Poisoning in Construction Workers

*Revised Edition*



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
Public Health Service  
Centers for Disease Control  
National Institute for Occupational Safety and Health

**CDC**  
CENTERS FOR DISEASE CONTROL

**This revised edition clarifies information about NIOSH-certified respirators for abrasive blasting operations (pages 11-13).**

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DHHS (NIOSH) Publication No. 91-116a



## Request for Assistance in

# PREVENTING LEAD POISONING IN CONSTRUCTION WORKERS

## WARNING!

**Lead poisoning may occur in workers during abrasive blasting, sanding, cutting, burning, or welding of bridges and other steel structures coated with lead-containing paints.**

The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing the lead poisoning\* of workers engaged in the maintenance, repainting, or demolition of bridges or other steel structures coated with lead-containing paints. NIOSH recently learned of 42 workers who developed lead poisoning while working on bridges. Operations such as abrasive blasting, sanding, burning, cutting, or welding on steel structures coated with lead-containing paints may produce very high concentrations of lead dust and fumes. Furthermore, the recent introduction of containment structures (enclosures designed to reduce environmental contamination by capturing particles of paint and used blasting material) may result in even higher airborne concentrations of lead. Lead dust at the worksite

may also result in contamination of workers' homes and automobiles.

For the construction industry, NIOSH and the Occupational Safety and Health Administration (OSHA) have recently recommended that exposure to lead dust and fumes be minimized by the use of engineering controls and work practices, and by the use of personal protective equipment (PPE)—including respirators—for additional protection [OSHA/NIOSH 1991]. Airborne lead concentrations and blood lead concentrations should be monitored to determine the effectiveness of controls and PPE. All new contracts of Federal, State, and local departments of transportation should include specifications for a mandatory program of worker protection from lead poisoning during the maintenance, repainting, or demolition of bridges and other steel structures.

NIOSH requests that the recommendations in this Alert be brought to the attention

\*For the purposes of this document, NIOSH has defined lead poisoning as a concentration of lead in whole blood (known by OSHA as a blood lead level, or BLL) exceeding 50 micrograms per deciliter ( $\mu\text{g}/\text{dl}$ ). See Table 4 for a list of actions required by the Occupational Safety and Health Administration (OSHA) general industry standard for various BLLs.

of workers and employers (including subcontractors) by general construction contractors, State departments of transportation (including worksite inspectors), labor union representatives, labor associations, editors of appropriate trade journals, and safety and health officials. Your assistance in this effort will help to achieve one of the national health objectives specified by *Healthy People 2000* [DHHS 1990], a statement of national goals for health promotion and disease prevention. These goals are the product of a national effort involving State health departments, national organizations, and many individuals. The goal for workers exposed to lead is to eliminate exposures that result in blood lead concentrations greater than 25 µg/dl of whole blood.

## BACKGROUND

Workers are potentially exposed to lead during work on bridges or other steel structures such as water and fuel storage tanks. Workers who may be exposed to lead include abrasive blasters, inspectors, iron workers (welders and cutters), painters, and laborers. In 1987, an estimated 44,000 persons worked in bridge, tunnel, and elevated-highway construction (Standard Industrial Classification Code [SIC] 1622), and an estimated 14,000 persons worked in wrecking and demolition (SIC 1795) [Bureau of the Census 1990].

An estimated 90,000 bridges in the United States are coated with lead-containing paints [Katauskas 1990]. According to a survey of State departments of transportation, lead-containing coatings were found on approximately 77% of U.S. bridges that were repainted between 1985 and 1989 [Steel Structures Painting Council 1991].

## Maintenance of Steel Structures

Before a new coating may be applied to bridges and other steel structures, deteriorated paint and corrosion must be removed and the metal surface must be properly prepared [Katauskas 1990]. In addition, all coatings of lead-based paints must be removed before another type of paint can be applied [Katauskas 1990]. This process is most commonly accomplished by using a portable device for abrasive blast cleaning. These devices are designed to deliver a high-velocity stream of abrasive to the metal surface. Compressed air is generally used, but some devices use water to deliver the abrasive. A variety of nonmetallic and metallic abrasives have been used, including silica sand, slag, and steel grit. The worker performing the blasting directs the blasting nozzle at the surface to be cleaned. As the paint is removed, small particles become airborne, and the used abrasives become contaminated with lead-containing paint particles.

Containment structures are used to reduce the release of lead into the environment by capturing paint chips, dust, and used abrasive. Where possible, containment structures are designed so that the used abrasives and debris are directed through chutes or tubes into a barge or hopper. Because the recovery systems in the containment structures are not completely effective, some of the material must be recovered manually by sweeping, shoveling, or vacuuming. Under the Resource Conservation and Recovery Act (RCRA), waste material must be tested, and if the leachable lead concentration is 5 parts per million (ppm) or greater, the material is classified as a hazardous waste [40 CFR\* 260].

\*Code of Federal Regulations. See CFR in references.

Containment structures are designed to reduce the dispersion of lead into the environment, but they may increase worker exposure to airborne lead. Current techniques for containment are not well defined and vary in their efficiency in preventing lead from being released into the environment. Some containment structures consist of tarpaulins or open mesh fabrics placed over the blasting area; some use rigid materials of wood, metal, or plastic to enclose the blasting area; and some use a combination of flexible and rigid materials. Large air-moving devices may be mounted on trucks and connected to the containment structures to exhaust dust-laden air. The exhausted air is passed through dust separation devices and filters before it is released to the atmosphere. This ventilation technique may also create a negative pressure within the containment structure and help reduce environmental contamination.

Workers may receive additional exposure at some sites when the containment structures (which may contain residual lead dust and debris) are disassembled and moved. Workers should be adequately protected while performing these operations.

### Potential for Exposure to Airborne Lead

At sites where workers performed bridge, tunnel, and elevated-highway construction (SIC 1622), OSHA reported airborne lead concentrations exceeding 200 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) for 65% of the samples collected between April 1984 and April 1988 [OSHA 1988]. Tables 1 and 2 summarize cases of occupational exposures to lead reported during abrasive blasting, sanding, burning, cutting, and welding. Most of the operations described were conducted outside containment structures. These data indicate that persons working at the jobsite outside the containment structure are also at

risk of exposure to lead. *Workers who do not shower and change into clean clothing before leaving the worksite may contaminate their homes and automobiles with lead dust.* Other members of the household may then be exposed to harmful amounts of lead [Grandjean and Bach 1986; Kaye et al. 1987; Matte et al. 1989; Baker et al. 1977].

### HEALTH EFFECTS OF LEAD EXPOSURE

The frequency and severity of medical symptoms increase with the concentration of lead in the blood. Many adults with blood lead levels (BLLs) of 80  $\mu\text{g}/\text{dl}$  or greater have symptoms or signs of acute lead poisoning, although in some individuals, symptoms may be so mild that they are overlooked [NIOSH 1978; Rosenstock and Cullen 1986]. Common symptoms of acute lead poisoning are loss of appetite, nausea, vomiting, stomach cramps, constipation, difficulty in sleeping, fatigue, moodiness, headache, joint or muscle aches, anemia, and decreased sexual drive. Severe health effects of acute lead exposure include damage to the nervous system, including wrist or foot drop, tremors, and convulsions or seizures. Acute lead poisoning from uncontrolled occupational exposures has resulted in fatalities [Hayhurst 1915].

Chronic lead poisoning may result after lead has accumulated in the body over time, mostly in the bone. Long after exposure has ceased, some physiological event such as illness or pregnancy may release this stored lead from the bone and produce adverse health effects such as impaired hemoglobin synthesis, alteration in the central and peripheral nervous systems, hypertension, effects on male and female reproductive systems, and damage to the developing fetus [Landrigan 1989]. These health effects may occur at BLLs below 50  $\mu\text{g}/\text{dl}$ .

**Table 1.—Airborne lead concentrations reported during operations on bridges and other painted steel structures**

Operation	Job	Exposure range during task ( $\mu\text{g}/\text{m}^3$ )	Comments
Bridge rehabilitation [New Jersey Department of Health 1988a]	Torch burner	220–6,000	Work conducted in semiconfined area
	Hammering and drilling	40–360	Workers were mechanically disturbing painted surface in semiconfined area
Bridge demolition (no containment structure) [New Jersey Department of Health 1988b]	Torch burner	110–1200	Workers were cutting beams on bridge
	Burner helper	330	These workers assisted burners who were cutting the bridge
	Power tool use	5–50	
Bridge demolition (no containment structure) [New Jersey Department of Health 1990]	Burner	180–1,800	
	Rivet removal	500–930	
Paint removal from boiler (no containment structure) [Adkison 1989]	Blaster	230–860	Samples were taken inside respirator
		640–1,400	Samples were taken outside respirator
	Power tool operators	80–790	Workers were spot cleaning an existing surface
Power plant (no containment structure) [Rekus 1988]	Burner	2,100–22,400	
Bridge repair (no containment structure) [Rekus 1988]	Welder	2,200–4,200	
	Blaster	10,400	

(Continued)

**Table 1 (Continued).—Airborne lead concentrations reported during operations on bridges and other painted steel structures**

Operation	Job	Exposure range during task ( $\mu\text{g}/\text{m}^3$ )	Comments
Bridge repair (continued)	Burner Blaster	840–4,900 1,070–1,120	
Paint removal from a tank [Lippy et al. 1988]	Abrasive blasting	490–870	Work conducted inside containment structure
	Carpenter	8	Work conducted outside containment structure
	Steam filter	40–50	Work conducted outside containment structure
	Blaster helper	90–560	Work conducted inside containment structure

### RELEVANT EXPOSURE CRITERIA AND REGULATIONS

In 1978, OSHA promulgated a comprehensive standard regulating occupational exposure to inorganic lead in general industry [29 CFR 1910.1025]. Under this standard, the permissible exposure limit (PEL) for inorganic lead is  $50 \mu\text{g}/\text{m}^3$  of air as an 8-hour time-weighted average (TWA). However, the construction industry was exempted from this regulation and has a  $200\text{-}\mu\text{g}/\text{m}^3$  PEL for inorganic lead [29 CFR 1926.55]. Unlike the OSHA standard for general industry, the construction standard does not require medical monitoring of workers exposed to lead or removal of workers from the job when they show elevated concentrations of lead in the blood. Specific medical monitoring recommendations for these workers are discussed in the section on conclusions and recommendations.

The NIOSH recommended exposure limit (REL) for lead is less than  $100 \mu\text{g}/\text{m}^3$  of air

as a TWA for up to 10 hours per day during a 40-hour workweek. This air concentration is to be maintained so that the worker's lead concentration remains below  $60 \mu\text{g}/100$  grams of whole blood (approximately equivalent to  $60 \mu\text{g}/\text{dl}$ ) [NIOSH 1988c; CDC 1990]. NIOSH is presently reviewing the data on the health effects of lead to determine whether our current recommendations need to be updated.

Several States have instituted programs to protect construction workers from the hazards of occupational lead exposure. For example, Maryland enacted in 1984 (and modified in 1988) a comprehensive standard regulating occupational lead exposure in construction work [Maryland Regulations Code 1988]. Under this standard, the permissible exposure limit for lead is  $50 \mu\text{g}/\text{m}^3$  as an 8-hour TWA. This standard must be incorporated in all contracts involving bridge work in Maryland. Connecticut is currently preparing similar requirements for inclusion in contracts [Connecticut Department of Transportation 1991].

**Table 2.—Airborne lead concentrations reported for case studies**

Case No.*	Location and description	Job	Range of airborne lead concentration during task ( $\mu\text{g}/\text{m}^3$ )	Comments
1	Connecticut, paint removal from bridge (with containment structures)	Blaster	4–540	Work conducted inside containment structure
		Groundsman	20–640 3,110–3,150 <sup>†</sup>  230–410 <sup>†</sup>	Work conducted outside containment structure
3	Louisiana, paint removal from bridge (with containment structures)	Blaster	2–730	Work conducted inside containment structure
5	New York, bridge demolition	Burners	600–4,000	
6	Kentucky, paint removal from bridge (with containment structures)	Blaster	3,690–29,400	Work conducted inside containment structure; samples taken outside respirator
		Blaster	9–190	Work conducted inside containment structure; samples taken inside respirator
		Groundsman	5–6,720	Work conducted outside containment structure

\*No samples were collected for Cases 2 and 4.

<sup>†</sup>Area samples.

## CASE REPORTS OF LEAD POISONING

NIOSH recently learned of 42 construction workers at 8 different worksites who developed lead poisoning (BLLs exceeding 50  $\mu\text{g}/\text{dl}$  of blood) while working on bridges [Mintz 1990; Rae 1990; Johnson 1990; CDC 1989; Marino et al. 1989; NIOSH 1991b]. The BLLs for these workers ranged from 51 to 160  $\mu\text{g}/\text{dl}$ . The mean BLL for the U.S.

population is 13.9  $\mu\text{g}/\text{dl}$ , and the upper 95th percentile is 25.0  $\mu\text{g}/\text{dl}$  [NCHS 1984]. The airborne concentrations of lead ranged from 2 to 29,400  $\mu\text{g}/\text{m}^3$  (see Table 2). At least 26 of the 42 cases of lead poisoning (62%) were workers employed at a site using a containment structure. The actual number of cases of occupational lead poisoning nationwide is much larger than 42, but it cannot be accurately determined since employers are not required to routinely measure lead concentration in the blood of exposed construction workers.

#### **Case No. 1**

A study now being conducted in Connecticut has identified four workers with lead poisoning at three different bridge sites [Mintz 1990]. Containment structures were used at all three sites. The workers' BLLs ranged from 51 to 66  $\mu\text{g}/\text{dl}$ , but none reported symptoms of lead intoxication. Personal breathing zone samples indicated airborne lead concentrations of 4 to 640  $\mu\text{g}/\text{m}^3$ . All workers wore respiratory protection (abrasive blasting, half-mask, or disposable respirators).

#### **Case No. 2**

In 1989, eight workers at a bridge site in Monroe, Louisiana, developed lead poisoning while working in a containment structure [Rae 1990]. The BLLs of these workers ranged from 56 to 146  $\mu\text{g}/\text{dl}$ . Their complaints included malaise, arm numbness, abdominal discomfort, joint and muscle aches, headache, and diarrhea. Airborne concentrations of lead were not reported.

#### **Case No. 3**

In May 1990, 12 bridge workers in Baton Rouge, Louisiana, developed lead poisoning while working in a containment structure [Johnson 1990]. The BLLs of affected workers ranged from 52 to 102  $\mu\text{g}/\text{dl}$ . Reported airborne concentrations of lead ranged from 2 to 730  $\mu\text{g}/\text{m}^3$ . The worker with the BLL of 102  $\mu\text{g}/\text{dl}$  developed joint pains and required hospitalization for intravenous chelation therapy.

#### **Case No. 4**

In March 1988, five workers developed lead poisoning during demolition of a bridge in Massachusetts [CDC 1989]. The BLLs of affected workers ranged from 67 to 160  $\mu\text{g}/\text{dl}$ .

All five workers reported symptoms consistent with lead poisoning. Four of the five workers were treated with intravenous chelation therapy. Airborne lead concentrations were not reported.

#### **Case No. 5**

In 1987, 11 workers who wore positive-pressure, air-supplied respirators developed lead poisoning during demolition of a bridge in New York [Marino et al. 1989]. The BLLs of these workers ranged from 52 to 120  $\mu\text{g}/\text{dl}$ . One worker with a BLL of 120  $\mu\text{g}/\text{dl}$  reported symptoms of muscle soreness, weakness, lack of appetite, nausea, and vomiting. Another worker with a BLL of 105  $\mu\text{g}/\text{dl}$  reported symptoms of headache, tiredness, and abdominal discomfort. Both workers required intravenous chelation therapy. Personal breathing zone concentrations of lead ranged from 600 to 4,000  $\mu\text{g}/\text{m}^3$ .

#### **Case No. 6**

In March 1991, NIOSH investigators began a study of lead exposures in 12 workers engaged in abrasive blasting and repainting of a bridge in Kentucky [NIOSH 1991b]. BLLs were measured during the first week of work and ranged from 5 to 48  $\mu\text{g}/\text{dl}$ . The BLLs were measured again after 1 month of exposure and ranged from 9 to 61  $\mu\text{g}/\text{dl}$ . Two workers had BLLs exceeding 50  $\mu\text{g}/\text{dl}$ . The airborne concentration of inorganic lead ranged from 5 to 29,400  $\mu\text{g}/\text{m}^3$ . Blasters wore continuous-flow abrasive blasting respirators. Other workers used half-mask, air-purifying respirators with high-efficiency particulate air (HEPA) filters. However, there was no complete respiratory protection program consistent with OSHA requirements [29 CFR 1910.134] and NIOSH recommendations [NIOSH 1987a; NIOSH 1987b]. Running water, coveralls, and clean change-rooms were not available at the site.

## CONCLUSIONS AND RECOMMENDATIONS

Lead poisoning may occur when workers inhale or ingest lead dust and fumes during abrasive blasting, sanding, cutting, burning, or welding of bridges and other steel structures coated with lead-containing paints. Data presented in this document reveal lead poisoning among workers who were wearing respirators. Therefore, a prudent policy is to minimize the risk of adverse health effects by keeping lead concentrations as low as possible and by using all available controls—including engineering controls, work practices, and respiratory protection. To help achieve the *Healthy People 2000* [DHHS 1990] objective of limiting worker blood lead concentrations to 25 µg/dl, NIOSH recommends the following measures for reducing lead exposure and preventing lead poisoning among workers involved in demolishing or maintaining bridges and other steel structures.

### Air Monitoring

An industrial hygienist or other qualified professional should perform an initial hazard assessment of the worksite to determine the composition of the paint. Environmental monitoring should also be performed to (1) measure worker exposure to airborne lead and other hazardous agents (e.g., silica and solvents), and (2) select the engineering controls and PPE required. Environmental monitoring should be performed as needed to measure the effectiveness of controls and to determine whether the proper respiratory protection is being worn. Air samples should be collected and analyzed according to NIOSH methods [NIOSH 1984] or their equivalent.

### Engineering Controls

Engineering controls should be used to minimize exposures to lead at the worksite. At a

minimum, airborne lead exposures should not exceed the current OSHA PEL for general industry (50 µg/m<sup>3</sup>). Whenever possible, engineering controls should include material substitution (i.e., repainting of structures with less toxic material), process and equipment modification, isolation or automation, and local and general exhaust ventilation. The appropriate types of controls vary with the operation.

### *Welding, Cutting, or Burning*

Before welding, cutting, or burning any metal coated with lead-containing materials, remove the coating to a point at least 4 inches from the area where heat will be applied [29 CFR 1926.354]. When removal of lead-containing paint is not feasible, use engineering controls (e.g., local exhaust ventilation) to protect workers who are welding, cutting, or burning lead-bearing materials. Such controls should be used to remove fumes and smoke at the source and to keep the concentration of lead in the breathing zone below the OSHA PEL. Contaminated air should be filtered before it is discharged into the environment well away from the source of intake air and other workers. Replace contaminated air with clean air [29 CFR 1926.353].

### *Surface Preparation*

When performing abrasive blasting, scaling, chipping, grinding, or other operations to remove lead-containing paint, use work practices that minimize the amount of dust generated. Less dusty blasting techniques include centrifugal blasting (using rotating blades to propel the abrasive, which is recovered and recycled), wet blasting (using high-pressure water with or without an abrasive, or surrounding the blast nozzle with a ring of water), and vacuum blasting (shrouding the nozzle with local exhaust ventilation) [Rex 1990]. Other methods that reduce dust include scraping,

heating and scraping, use of needle guns, and chemical removal.

Materials containing crystalline silica should *not* be used as abrasives for any blasting operation, including paint removal [NIOSH 1988b]. Crystalline silica is associated with silicosis and is classified by NIOSH as a potential occupational carcinogen [NIOSH 1988d].

Lead-containing dust and abrasive materials should be removed daily by using vacuums equipped with HEPA filters or by using wet methods to prevent lead-containing particles from becoming airborne [Steel Structures Painting Council 1991].

#### ***Work Inside Containment Structures***

Containment structures are often used to reduce environmental contamination by capturing particles of paint and used blasting materials. Although such structures reduce environmental contamination, they may also increase lead exposures for workers (see Figure 1). Ventilation should be provided to reduce the airborne concentration of lead and increase visibility. Containment structures should be designed to optimize the flow of ventilation air past the worker(s). Insofar as possible, workers should be upstream from the blasting operation to reduce exposure to lead dust entrained in the ventilation air and to improve visibility. Designs for the containment structure and ventilation systems should be specific to each task because of varied conditions at the worksite (i.e., the type of steel structure being blasted, the type of blasting methods, and the type of materials used for construction).

#### ***Contract Specifications***

All new contracts of Federal, State, and local departments of transportation should include specifications for a mandatory program of worker protection from lead poisoning during

the maintenance, repainting, or demolition of bridges and other steel structures.

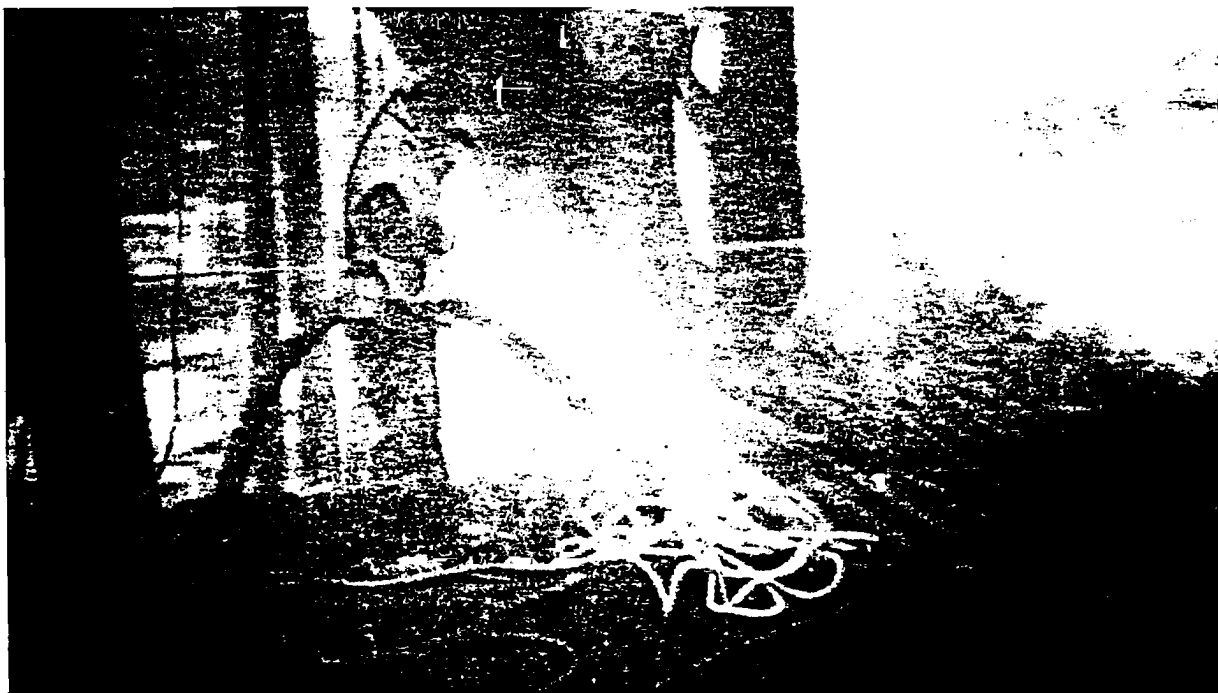
### **Personal Hygiene Practices**

Personal hygiene is an important element of any program for protecting workers from exposure to lead dust [Ulenbelt et al. 1990]. OSHA requires employers to provide adequate washing facilities at the worksite so that workers can remove lead particles that accumulate on the skin and hair [29 CFR 1926.51]. Showers should also be available [OSHA/NIOSH 1991].

All workers exposed to lead should wash their hands and faces before eating, drinking, or smoking, and they should not eat, drink, or use tobacco products in the work area. Tobacco products (cigarettes, cigars, chewing tobacco, etc.) and food items should not be permitted in the work area. Contaminated work clothes should be removed before eating.

Workers should change into work clothes at the worksite. Work clothes include disposable or washable coveralls. Street clothes should be stored separately from work clothes in a clean area provided by the employer. Separate lockers or storage facilities should be provided so that clean clothing is not contaminated by work clothing and shoes. Workers should change back into their street clothes after washing or showering and before leaving the worksite to prevent the accumulation of lead dust in the workers' cars and homes and thereby protect family members from exposure to lead. Cars should be parked where they will not be contaminated with lead.

Employers should arrange for the laundering of protective clothing; or, if disposable protective clothing is used, the employer should maintain an adequate supply at the worksite and arrange for its safe disposal according to applicable Federal [40 CFR 260] and State regulations.



**Figure 1.** Construction worker using a HEPA-filter vacuum inside a containment structure. Note that the worker is obscured by a high airborne concentration of dust.

## Warning Signs

Warning signs should be posted to mark the boundaries of lead-contaminated work areas. These signs should follow the example presented in the OSHA general industry standard [29 CFR 1910.1025], which warns about the lead hazard and prohibits eating and drinking in the area. Such signs should also specify any PPE required (for example, respirators). The sample sign in Figure 2 contains all the information needed for a lead-contaminated work area where respirators are required.

## Personal Protective Equipment (PPE)

Engineering controls and good work practices should be used to minimize worker exposure to lead. Because of the variable exposure concentrations in the construction industry

and the difficulty of monitoring a mobile workforce, PPE should be used whenever workers are potentially exposed to lead [OSHA/NIOSH 1991]. The use of PPE should supplement the continued use of engineering controls and good work practices.

### *Protective Clothing*

Protective clothing not only shields workers from the hazards of welding and abrasive blasting, but it also minimizes the accumulation of lead on the worker's skin and hair. Workers should change into washable coveralls or disposable clothing before entering the contaminated work area. Because wearing PPE (especially protective clothing) can contribute to the development of heat stress [NIOSH/OSHA/USCG/EPA 1985], a potentially serious illness, regular monitoring and other preventive measures are vital [NIOSH 1986].

**WARNING!**  
**LEAD WORK AREA—POISON**  
**NO EATING OR SMOKING**  
**RESPIRATORS REQUIRED**

**Figure 2.** Sample of warning sign for lead work area requiring respirators.

To minimize the amount of lead that may accumulate in the worker's car and home and to protect the members of the worker's household, lead-contaminated clothing (including work shoes) should be left at the worksite for cleaning or disposal. Workers who are welding, cutting, or burning should wear nonflammable clothing [NIOSH 1988a].

### ***Respiratory Protection***

Effective source control measures (such as containment or local exhaust ventilation) should be implemented to minimize worker exposure to lead. NIOSH prefers such measures as the primary means of protecting workers; but source control at construction sites is often ineffective, and airborne lead concentrations may be high or may vary unpredictably. Therefore, respiratory protection is also necessary for certain operations such as blasting, sweeping, and vacuuming, and for other jobs as determined at the worksite by an industrial hygienist or other qualified professional. However, respirators are the least preferred method of controlling lead exposure, and *they should not be used as the only means of preventing or minimizing exposures*. The use of respirators should supplement the continued use of

engineering controls and good work practices [OSHA/NIOSH 1991].

When respirators are used, the employer must establish a comprehensive respiratory protection program as outlined in the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a], and as required in the OSHA respiratory protection standard [29 CFR 1910.134]. Important elements of the OSHA respiratory protection standard are (1) an evaluation of the worker's ability to perform the work while wearing a respirator, (2) regular training of personnel, (3) periodic environmental monitoring, and (4) respirator fit testing, maintenance, inspection, cleaning, and storage. The program should be evaluated regularly by the employer. Without a complete respiratory protection program, workers will not receive the protection anticipated.

Respirators should be selected by the person who is in charge of the program and knowledgeable about the workplace and the limitations associated with each type of respirator. Because exposures to lead during construction may vary substantially throughout a workshift and between days, the highest anticipated exposure should be used to determine the appropriate respirator for each job.

Respirator selection should be made according to the guidelines in Table 3. Employers must use respirators that are certified by NIOSH and the Mine Safety and Health Administration (MSHA) [NIOSH 1991a].

NIOSH type CE respirators are required for use by abrasive blasting operators [29 CFR 1910.94]. Currently, only continuous-flow respirators are certified by NIOSH for abrasive blasting [29 CFR 1910.94], but positive-pressure, supplied-air respirators would provide greater protection [NIOSH 1987b; 30 CFR 11]. The continuous-flow

**Table 3.—NIOSH-recommended respiratory protection for workers exposed to inorganic lead**

Condition	Minimum respiratory protection*
$\leq 0.5 \text{ mg/m}^3$ <sup>†</sup> (10 × PEL) <sup>‡</sup>	Any air-purifying respirator with a high-efficiency particulate filter
$\leq 1.25 \text{ mg/m}^3$ (25 × PEL)	Any powered, air-purifying respirator with a high-efficiency particulate filter, or  Any supplied-air respirator equipped with a hood or helmet and operated in a continuous-flow mode (for example, type CE abrasive blasting respirators)
$\leq 2.5 \text{ mg/m}^3$ (50 × PEL)	Any air-purifying, full-facepiece respirator with a high-efficiency particulate filter, or  Any powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter
$\leq 50 \text{ mg/m}^3$ (1,000 × PEL)	Any supplied-air respirator equipped with a half-mask and operated in a pressure-demand or other positive-pressure mode
$\leq 100 \text{ mg/m}^3$ (2,000 × PEL)	Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode
Planned or emergency entry into environments containing unknown concentrations or concentrations above 100 mg/m <sup>3</sup> (2,000 × PEL)	Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode, or  Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode
Firefighting	Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode
Escape only	Any air-purifying, full-facepiece respirator with a high-efficiency particulate filter, or  Any appropriate escape-type, self-contained breathing apparatus

\*Only NIOSH/MSHA-approved equipment should be used.

<sup>†</sup>Less than or equal to 0.5 mg/m<sup>3</sup>.

<sup>‡</sup>Multiple of the OSHA PEL for general industry.

respirators are recommended by NIOSH only for airborne concentrations less than or equal to 25 times the OSHA PEL for general industry—50  $\mu\text{g}/\text{m}^3$  [NIOSH 1987b]. Furthermore, manufacturer's instructions regarding quality of air, air pressure, and inside diameter and length of hoses must be strictly followed. Use of longer hoses, hoses having a smaller inside diameter, or hoses with kinks and bends may restrict the flow of air to the respirator.

In all cases, respiratory protection should be donned before entering the contaminated work area, and it should be removed only after the worker has left that area.

## **Medical Surveillance**

### ***Medical Monitoring***

BLLs are currently the best indicator of personal lead exposure. Workers potentially exposed to lead should therefore be monitored for the presence of lead in blood and the effects of lead on the blood-forming system. This assessment is necessary to ensure that engineering controls, personal hygiene practices, and PPE are preventing lead exposure.

The OSHA general industry standard contains provisions for the medical monitoring of workers exposed to lead [29 CFR 1910.25]. NIOSH supports the use of these provisions for construction workers but acknowledges that these workers may require more frequent blood lead monitoring (for example, monthly) than specified in the OSHA standard because of their highly variable, unpredictable exposures to lead. Similar provisions for more frequent monitoring have also been specified by the Connecticut Department of Transportation to be included in bid specifications for construction work involving lead exposure [Connecticut Department of Transportation 1991].

Lead concentration in the blood should be measured for any exposed worker who experiences symptoms or signs of lead poisoning. Analyses of blood should be performed only by OSHA-listed laboratories (a listing is available from the OSHA Analytical Laboratory in Salt Lake City, Utah; telephone, 801-524-4270).

The results of all laboratory analyses, a description of the worker's job, and any available data on possible exposures should be evaluated by a physician with experience and training in occupational health. To detect the health effects of excess lead exposure and to provide a baseline for comparison with future results, an occupational health interview and a physical examination should be performed before job placement, before returning to work after being removed from the job because of elevated blood lead concentrations, and annually for all workers exposed to lead.

### ***Medical Protection***

The OSHA lead standard for general industry [29 CFR 1910.1025] requires that certain actions be taken at given concentrations of lead in the blood (see Table 4). These actions are designed to prevent many of the adverse health effects of lead exposure.

### ***Mandatory Reporting***

Presently, 15 States require laboratories and health care providers to report cases of elevated blood lead concentrations to the State health department [Freund et al. 1989]. Table 5 provides a list of the States that require such reporting and the concentration that requires reporting for each State. To monitor progress in achieving the *Healthy People 2000* objective for lead concentrations in blood [DHHS 1990], cases of elevated BLLs should be reported to all State health departments.

**Table 4.—Actions required by the OSHA general industry standard for various lead concentrations in blood (BLLs)**

Number of tests	BLL* (µg/dl)	Action required
1	≥40 <sup>†</sup>	Notification of worker in writing; medical examination of worker and consultation
3 (average)	≥50	Removal of worker from job with potential lead exposure
1	≥60	Removal of worker from job with potential lead exposure
2	<40 <sup>§</sup>	Reinstatement of worker in job with potential lead exposure

\*In the OSHA general industry standard for lead, BLLs are reported in micrograms per 100 grams (µg/100 g) of whole blood, which is approximately equal to µg/dl.

<sup>†</sup>Greater than or equal to 40.

<sup>§</sup>Less than 40.

## Training

Workers should receive training [29 CFR 1926.21] that includes the following:

- Information about the potential adverse health effects of lead exposure
- Information about the early recognition of lead intoxication
- Information in material safety data sheets for new paints or coatings that contain lead or other hazardous materials [29 CFR 1926.59]
- Instruction about heeding signs that mark the boundaries of lead-contaminated work areas
- Discussion of the importance of personal hygiene practices in reducing lead exposure

- Instruction about the use and care of appropriate protective equipment (including protective clothing and respiratory protection)
- Information about specific work practices for working safely with lead-containing paints

## ACKNOWLEDGMENTS

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For medical information, please contact

Paul Seligman, M.D., M.P.H.  
Telephone: (513) 841-4353

**Table 5.—State agencies that require the reporting of individuals with elevated lead concentrations in blood (BLLs)**

<b>State</b>	<b>Contact person</b>	<b>Concentration that requires reporting (µg/dl)</b>
Alabama	Charles Woernle, M.D., M.P.H. State Epidemiologist Department of Public Health 434 Monroe Street Montgomery, AL 36130 205-242-5131	15
California	Neil Maizlish, Ph.D. Occupational Health Program California Department of Health Services 2151 Berkeley Way, Room 504 Berkeley, CA 94704 415-540-2115	25
Colorado	Jane McCammon Colorado Department of Health Epidemiology Division 4210 E. 11th Ave. Denver, CO 80220 303-331-8330	25
Connecticut	Narda Tolentino, M.P.H. Connecticut Department of Health Services Environmental Epidemiology and Occupational Health (EEOH) 150 Washington Street Hartford, CT 06106 203-566-8167	25
Illinois	Jane Keller Occupational Disease Registry Illinois Department of Public Health Division of Epidemiologic Studies 605 W. Jefferson Springfield, IL 62761 217-785-1873	25
Iowa	Joann Muldoon Environmental Epidemiology Section Iowa Department of Public Health Lucas State Office Building Des Moines, IA 50319 515-281-5643	25

(Continued)

\* Questions regarding these reporting requirements should be directed to the contact person in each State.

**Table 5 (Continued).—State agencies that require the reporting of individuals with elevated lead concentrations in blood (BLLs)**

<b>State</b>	<b>Contact person</b>	<b>Concentration that requires reporting (µg/dl)</b>
Maryland	Ellen Coe, R.N., M.P.H. Health Registries Division Maryland Department of the Environment 2500 Broening Highway Baltimore, MD 21224 301-631-3851, FAX 301-631-3198	25
Massachusetts	Richard Rabin Massachusetts Department of Labor and Industries Division of Occupational Hygiene 1001 Watertown Street Newton, MA 02165 617-969-7177	15
Michigan	Larry Chadzynski, R.S., M.P.H. Office of the Director Michigan Department of Public Health 3423 N. Logan/Martin Luther King Blvd. P.O. Box 30195 Lansing, MI 48909 517-335-8637	15
New Jersey	Barbara Gerwel, M.D. Occupational Disease Prevention Program New Jersey Department of Health C N 360, John Fitch Plaza Trenton, NJ 08625 609-984-1863	25
New York	Robert Stone, Ph.D. New York State Department of Health 2 University Place - Room 155 Albany, NY 12203-3313 518-458-6228	25
Oregon	Jane Gordon, Ph.D. Deputy State Epidemiologist Oregon Health Division 1400 SW 5th Avenue Portland, OR 97201 503-229-5821	25

(Continued)

**Table 5 (Continued).—State agencies that require the reporting of individuals with elevated lead concentrations in blood (BLLs)**

State	Contact person	Concentration that requires reporting (µg/dl)
Texas	Janet Pichette Texas Department of Health 1100 West 49th Street Austin, TX 78756 512-458-7268	40
Utah	David J. Thurman, M.D., M.P.H. Bureau of Epidemiology Utah Department of Health P.O. Box 16660 Salt Lake City, UT 84116-0660 801-538-6191	30 (≥18 years of age) 20 (<18 years of age)
Wisconsin	Larry Hanrahan, M.S. Wisconsin Department of Health and Social Services One W. Wilson Street, Box 309 Madison, WI 53701 608-267-7173	25

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**NIOSH**

**ALERT**



## Lead Poisoning in Construction Workers

### WARNING!

Workers are at risk of lead poisoning during the maintenance, repainting, or demolition of bridges or other steel structures coated with lead-containing paint.

Take the following steps to protect yourself and your family from lead exposure:

- Be aware of the health effects of lead exposure (see p. 3 of the NIOSH Alert, *Request for Assistance in Preventing Lead Poisoning in Construction Workers*) and discuss with your doctor any symptoms or concerns that may be related to lead poisoning.
- Participate in any blood lead or air monitoring program offered by your employer.
- Use engineering controls such as source containment and local exhaust ventilation to minimize exposures to lead.
- Be aware that the highest lead concentrations may occur inside containment structures.
- Use respirators when blasting, sweeping, vacuuming, or performing other high-risk jobs (as determined by an industrial hygienist or other qualified professional).
- Change into disposable or washable coveralls at the worksite.
- Do not eat, drink, or use tobacco products in the work area.
- Wash your hands and face before eating, drinking, or smoking outside the work area.
- Shower and change into clean clothing before leaving the worksite to prevent contaminating homes and automobiles.



Please tear out and post. Distribute copies to workers.

See back of sheet to order complete Alert.

For additional information, see the NIOSH Alert, Request for Assistance in Preventing Lead Poisoning in Construction Workers [DHHS (NIOSH) 90-116a], or call 1-800-35-NIOSH. Single copies are available free from the following:

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and Health



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
Public Health Service  
Centers for Disease Control





**NIOSH**

# *ALERT*

AUGUST 1992

REQUEST FOR ASSISTANCE IN

## **Preventing Worker Injuries and Deaths Caused by Falls From Suspension Scaffolds**



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
Public Health Service  
Centers for Disease Control  
National Institute for Occupational Safety and Health

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DHHS (NIOSH) Publication No. 92-108



## Request for Assistance in

# PREVENTING WORKER INJURIES AND DEATHS CAUSED BY FALLS FROM SUSPENSION SCAFFOLDS

### WARNING!

Workers may die or be injured if scaffold equipment and fall protection systems are defective or misused.

The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing worker injuries and deaths caused by falls from suspension scaffolds. "Suspension scaffold" means one or more working platforms suspended by ropes or other means from an overhead structure. Recent investigations by NIOSH suggest that fatal falls occur as a result of defective scaffold equipment, improper installation or operation, improper training of workers, or a failure to use appropriate personal fall protection equipment. This Alert describes five incidents resulting in six deaths caused by falls from suspension scaffolds.

Safety regulations of the Occupational Safety and Health Administration (OSHA) establish specific requirements for suspension scaffolds and their operation, including the use of fall protection systems\* (Figure 1). Every employer, supervisor, and worker involved in work from suspension scaffolds must comply with these

\*Fall protection systems consist of body belt or harness systems (personal fall arrest systems) used independently or in combination with guardrail systems.

regulations. NIOSH requests editors of trade journals, safety and health officials, and employers in the construction trades to bring the recommendations in this Alert to the attention of construction supervisors and workers.

### BACKGROUND

Falls are a leading cause of traumatic occupational death. For the period 1980–85, the NIOSH National Traumatic Occupational fatalities (NTOF) database indicates that falls accounted for nearly 10% (3,491 of 36,210) of all traumatic occupational deaths for which a cause was identified [Bobick et al. 1990; NIOSH 1991a]. For 1986, the U.S. Department of Labor indicates that falls accounted for 8% (289 of 3,610) of all occupational fatalities from trauma [BLS 1988].

Fatal falls from scaffolds during the period 1980–85 accounted for 17% of all falls from elevations (461 of 2,705) and were second only to falls from buildings [Bobick 1988; NIOSH 1991a].

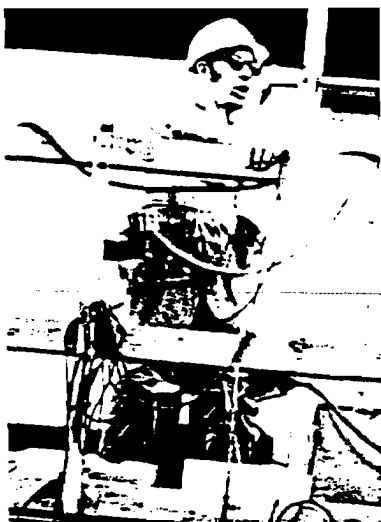


Figure 1. Worker with fall protection systems in place.

Falls from scaffolds accounted for 21% (82 of 386 incidents and 86 deaths) of fatal falls from working surfaces reported for the period 1974 to 1978 [OSHA 1979]. Suspension scaffolds were involved in 30% (25 of 82 incidents and 27

deaths) of the falls from scaffolds. Of the 25 falls from suspension scaffolds, 68% (17) involved scaffold equipment failure. Personal fall protection equipment was used in only three of these incidents, but it was used improperly in each case. In one incident, a worker fell out of his improperly fastened safety belt; in the other two incidents, excessively long lanyards broke or separated after victims fell 30 feet:

## CURRENT AND PROPOSED OSHA REGULATIONS

OSHA regulations were promulgated in 1971 to protect workers from the hazards of working from scaffolds in both general industry [29 CFR<sup>†</sup> 1910.28] and the construction industry [29 CFR 1926.451]. However, falls from scaffolds continued to occur, and in 1986, OSHA proposed to revise the construction industry safety regulations addressing all types of scaffolds [51 Fed. Reg.<sup>‡</sup> 42680 (1986)].

<sup>†</sup>Code of Federal Regulations. See CFR in references.

<sup>‡</sup>Federal Register. See Fed. Reg. in references.

The proposed regulations would apply to the design, construction, and use of all scaffolds in construction. Instead of specification standards, the proposed regulations would use performance criteria to reduce the danger of slipping or falling from scaffolds.

The proposed regulations provide general requirements for all scaffolds regarding capacity, construction, access, use, and fall protection. In addition, they include provisions for the following:

- Use of a competent person (as defined in 29 CFR 1926.32) to inspect scaffolds and equipment before use
- Use of scaffold components capable of supporting proper loads
- Proper shielding of ropes from corrosive processes or heat
- Use of both guardrail systems and body belt or harness systems for work from suspension scaffolds

OSHA has scheduled final action on the proposed regulations for scaffolds and fall protection systems in 1992 [Occup Saf & Health Rep 1992].

## CASE REPORTS

The NIOSH Fatal Accident Circumstances and Epidemiology (FACE) Program has been investigating fall-related fatalities among workers since October 1988. The following subsections present findings from five case reports of falls from suspension scaffolds that resulted in the deaths of six workers.

### **Case No. 1—Two Deaths**

On November 15, 1988, a 53-year-old male painting foreman and a 28-year-old male painter died when the scaffold from which they were working collapsed, causing them to fall nearly 48 feet to the ground. The men were painting the exterior of a 48-foot-high, 56-foot-diameter storage tank. They were painting the side of the tank from a two-point suspension scaffold supported by two steel outriggers. The scaffold manufacturer specified 600 pounds of counterweight for this scaffold and load, but the painters had rigged the scaffold using only 200 pounds of counterweight (100 pounds per outrigger). The outriggers were not tied off or otherwise secured.

No personal fall protection equipment was being used by either worker. While the two men were working on the scaffold, their weight caused the outriggers to slip, and the scaffold, rigging, and victims fell to the ground [NIOSH 1989c].

### **Case No. 2—One Death**

On December 19, 1988, a 27-year-old male cement finisher died when he fell from a suspension scaffold and his safety lanyard snapped. The victim and a coworker were dismantling suspended scaffolding at the 160-foot level inside a 172-foot-high, circular concrete silo. Both men were wearing safety belts with nylon rope lanyards secured to independent lifelines.

The accident occurred when the victim lost his balance and fell off an unguarded end of the scaffold. The coworker stated that he saw the victim fall and jerk upward as the lanyard caught him. When the victim's weight dropped back on the lanyard, it snapped, allowing him to fall onto a concrete floor.

Examination of the lanyard after the event showed burn damage at several places,

including the point of failure. The employer did not control inspection or distribution of this fall protection equipment. Instead, the equipment was kept in a common supply bin where the workers could readily obtain it when needed and return it when work was completed. The lanyard had been returned to the storage bin even though it had probably been damaged earlier during cutting and welding operations [NIOSH 1989b].

### **Case No. 3—One Death**

On March 15, 1989, a 33-year-old male caulking mechanic died when the scaffold on which he was working failed and caused him to fall 60 feet to the ground. The victim and a coworker were caulking the exterior skin plate joints and windows of a new seven-story building. Most of the work on the lower levels of the building had previously been completed using a personnel hoist. The upper floors of the building could not be reached with this device, so the crew brought a suspension scaffold to the site on the day of the incident.

Upon arrival, the crew found that workers from a window-washing firm had already rigged a two-point suspension scaffold on the building. An arrangement was made for one crew (containing one worker from each company) to work from the caulker's manlift while a second crew worked from the window washer's two-point suspension scaffold. The victim and one worker from the window-washing firm then ascended the building using the two-point suspension scaffold and began work at the sixth floor. Although the victim and his coworker had brought safety belts and lifelines to the site, this equipment had been left in the company truck, and none of the four workers were using any type of fall protection equipment.

When work was completed at the sixth floor, the men began their descent. Suddenly, the

victim's end of the scaffold dropped to a vertical position. The victim fell from the scaffold to the ground 60 feet below. The second man on the scaffold (the window washer) managed to cling to the scaffold and a nearby window ledge until he could be rescued.

Inspection of the scaffold hoist revealed a defect in a centrifugal safety brake. This defect and the victim's possible failure to release the parking brake before beginning his descent caused one end of the scaffold to drop [NIOSH 1989a].

#### **Case No. 4—One Death**

On October 21, 1989, a 37-year-old male painter died when the platform he was working from fell 65 feet inside a municipal water storage tank. The victim was a member of a three-man crew that was using an improvised suspension scaffold to paint the interior of the 68-foot-tall, 32-foot-diameter water tank. The scaffold consisted of an aluminum ladder used as a platform and secured to steel "stirrups" made of steel bar stock bent into a box shape and attached to each end of the ladder. Wire cables from each stirrup ran to a common tie-off point. A cable from this common tie-off was rigged to a block and tackle used from ground level to raise and lower the platform. The block and tackle supporting the system was secured to a vertical steel pipe on top of the tank with a cable that was fashioned into a loop by U-bolting the dead ends of a piece of wire rope.

The victim had been painting from one end of this scaffold while wearing a safety belt and lanyard attached to an independent lifeline. When the victim finished painting, he unhooked his lanyard from his lifeline and moved along the ladder platform to a position where he could hand his paint spray gun to the foreman (who was at the top of the tank). As

the foreman took the spray gun, he heard a "pop" and saw the scaffold and the victim fall 65 feet to the floor of the tank.

Investigation of the incident revealed that the two U-bolts on the loop of cable supporting the block and tackle had loosened enough to allow the cable ends to slip through, causing the scaffold to fall. This particular rig had been used without incident every day for 2 weeks preceding this fatal fall [NIOSH 1990a].

#### **Case No. 5—One Death**

On November 20, 1989, a 39-year-old painter died after falling 40 feet when a scaffold suspension rope broke. The victim was a member of a three-man crew engaged in the abrasive blasting and painting of the interior of a 48-foot-high, 30-foot-diameter steel water tank.

Three separate two-point suspension scaffolds were used to reach the interior walls of the tank. The scaffolds abutted each other in a U-shaped configuration. The center scaffold platform was overlapped by one end of each of the other two scaffolds. Suspension ropes were located at each end of the center platform and at the outer ends of the two other platforms. The platform unit was raised by alternately raising each suspension point a few feet at a time.

Two men were involved in this operation when the incident occurred. The victim was standing on an outer end of the platform and was pulling on the suspension rope to raise that end of the scaffold. He fell when the rope broke and his end of the platform dropped to a vertical position. The victim was not using personal fall protection equipment although it was available and was being used by the second painter.

An investigation revealed that the 5/8-inch nylon hoist rope had broken at a point where it had been burned some time before the incident [NIOSH 1990b].

## CONCLUSIONS

The fatal incidents reported here all involved violations of OSHA regulations for scaffolds. These regulations include the use of proper scaffold equipment, appropriate installation of equipment, use of proper operating procedures, use of prescribed personal fall protection equipment, and adequate training of workers.

None of the deaths described here would have occurred if the existing and proposed OSHA regulations for the safe use of scaffolds had been observed.

## RECOMMENDATIONS

NIOSH recommends the following measures to prevent serious injuries and fatal falls while working from suspension scaffolds:

1. Comply with the current and proposed OSHA regulations for working with scaffolds.
2. Assure that design and construction of scaffolds conform with OSHA requirements.
3. Shield scaffold suspension ropes and body belt or harness system droplines (lifelines) from hot or corrosive processes, and protect them from sharp edges or abrasion.

4. Inspect all scaffolds, scaffold components, and personal fall protection equipment before each use.
5. Provide personal fall protection equipment and make sure that it is used by all workers on suspension scaffolds.
6. Use structurally sound portions of buildings or other structures to anchor droplines for body belt or harness systems and tiebacks for suspension scaffold support devices. Droplines and tiebacks should be secured to separate anchor points on structural members.
7. Provide proper training for all workers who use any type of suspension scaffold or fall protection equipment.
8. Follow scaffold manufacturers' guidance regarding the assembly, rigging, and use of scaffolds.

These recommendations are discussed briefly in the following subsections. Please note that an earlier NIOSH Alert [NIOSH 1991b] presents recommendations for preventing electrocutions during work with scaffolds near overhead power lines.

### Compliance with OSHA regulations

Employers and workers must comply with the current OSHA regulations for working with scaffolds [29 CFR 1910.28, 1926.451]. Furthermore, they should

- consider all provisions of the OSHA proposed rulemaking for safe use of scaffolds in construction [51 Fed. Reg. 42680 (1986)], and

- incorporate additional safety provisions as appropriate to strengthen their safety programs.

### **Design and Construction of Scaffolds**

The design and construction of scaffolds must conform with OSHA requirements concerning type of equipment, rated capacities, construction methods, and use. Each scaffold and scaffold component must be capable of supporting its own weight plus at least four times the maximum intended load without failure. Each suspension rope must be capable of supporting at least six times the maximum intended load.

### **Shielding of Ropes**

Suspension ropes and droplines for body belt or harness systems should be shielded from

- heat-producing processes such as welding,
- acids or other corrosive substances, and
- sharp edges or abrasions.

Such ropes should be made from material that is not adversely affected by heat or by acids or other corrosives.

### **Inspection**

Employers should require a competent person to inspect all scaffolds and scaffold components for visible defects before use on each workshift. Scaffolds should be erected, moved, dismantled, or altered only under the supervision of a competent person.

All components of personal fall protection equipment (including body belts or harnesses, lanyards, droplines, trolley lines, and

points of anchorage) should be inspected by a competent person before use. Any visibly damaged or worn equipment should be removed from service immediately.

### **Use of Fall Protection Equipment**

Employers should provide appropriate fall protection systems and ensure their use by all workers on suspension scaffolds. Generally, these workers should be protected by a Type I guardrail system<sup>§</sup> or a combination of body belt or harness system with a Type II guardrail system.\*\*

However, when single-point and two-point adjustable suspension scaffolds are used, workers must be protected by both a body belt or harness system and a Type I or Type II guardrail system. Also, when boatswain chairs, catenary scaffolds, and float scaffolds are used, workers must be protected only by a body belt or harness system.

### **Use of Structural Members as Anchor Points**

Structurally sound portions of buildings or other structures must be used to anchor droplines for body belt or harness systems and tiebacks for suspension scaffold support devices. Droplines and tiebacks should be secured to separate anchor points of structural members. Owners, architects, and engineers planning renovation or designing new facilities should incorporate strategically located anchor points on structural members of buildings for future exterior maintenance and repair work.

<sup>§</sup>Type I guardrail systems are those capable of providing adequate fall protection without the use of body belts.

\*\*Type II guardrail systems are those that delineate the scaffold edge, restrain movement, provide handholds, and prevent misstepping. Type II systems must be supplemented by body belt or harness systems to provide adequate fall protection [51 Fed. Reg. 42680 (1986)].

## Proper Training of Workers

Employers should provide workers with proper training, including the manufacturers' recommendations for installing and operating suspended scaffold systems and for using personal fall protection equipment. Untrained personnel should never be permitted to work from any type of suspension scaffold.

## ACKNOWLEDGMENTS

Dwayne Smith and Ronald Stanevich, Division of Safety Research, NIOSH, were the principal contributors to this Alert. Comments or questions concerning this Alert should be directed to Thomas R. Bender, M.D., Director, Division of Safety Research, National Institute for Occupational Safety and Health, 944 Chestnut Ridge Road, Morgantown, WV 26505-2888; telephone, (304) 291-4595.

We greatly appreciate your assistance, which is crucial to protecting the lives of American workers.



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Centers for Disease Control

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# NIOSH ALERT

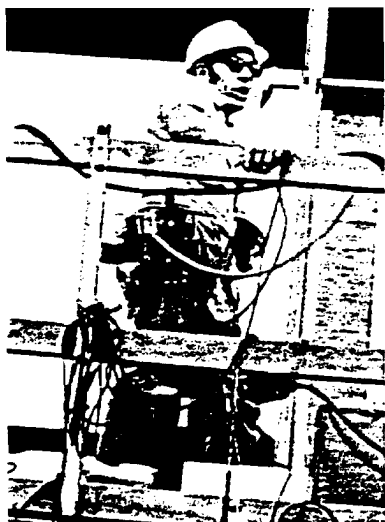
## Preventing Falls from Suspension Scaffolds

### WARNING!

**Workers may die or be injured if scaffold equipment and fall protection systems are defective or misused.**

Take the following steps to protect yourself if you are working from suspension scaffolds:

- **Always** use appropriate fall protection when working from suspension scaffolds. Generally, both guardrail systems and body belt or harness systems should be used.
- Ensure that a competent person has inspected all scaffolds, scaffold parts, and personal fall protection equipment **before each use**.
- Shield scaffold suspension ropes and droplines for body belt or harness systems during the following:
  - Hot processes such as welding
  - Processes that use acids or other corrosives
  - Processes that involve sharp edges or abrasion
- Use structurally sound portions of buildings or other structures to anchor droplines or body belt or harness systems and tiebacks for suspension scaffold support devices. Droplines and tiebacks should be secured to separate anchor points on structural members.
- Participate in any training programs offered by your employer.



Worker with fall protection systems in place.

For additional information, refer to *NIOSH Alert: Request for Assistance in Preventing Worker Injuries and Deaths Caused by Falls from Suspension Scaffolds* [DHHS (NIOSH) 92-108], or call 1-800-35-NIOSH. Single copies of the Alert are available from the following:

Publications Dissemination, DSDTT  
National Institute for Occupational Safety  
and Health  
4676 Columbia Parkway  
Cincinnati, OH 45226  
Telephone: (513) 533-8287



U.S. Department of Health and Human Services  
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and Health

*Please tear out and post. Distribute copies to workers.*