6.

Technologies for Controlling Work-Related Injuries

LIST OF TABLES

6. Technologies for Controlling Work-Related Injury

Injuries are caused by "abnormal energy transfers or interferences with energy transfer" (198). One analytical method breaks the injury-causing event into three parts: 1) the source of hazard, 2) its transmission, 3) and the worker; this method is patterned after the traditional public health model of disease transmission ("agent," "vector," and "host").

Control technologies suggested by this approach consider: control at the source of energy, control of transmission of energy, and control at the worker. Although there are many similarities between safety engineers' approach to injury control and the public health approach, their terminology and methods have usually been quite different. Safety engineers have tended to use codes, standards, and models of "good practice" that are oriented around particular topics: fire prevention, electrical safety, design of machinery, plant layout, etc.

This chapter describes how designers and engineers can plan sites, plant layout, and equipment design in order to prevent work-related injury. "Safe" design presents particular difficulties in the construction industry where constantly changing conditions create constantly changing workplace hazards against which workers must be protected. In manufacturing, the worksite is relatively more stable but there is still a great deal of worker exposure to hazardous releases of energy. Fire and explosion prevention is an area that not only can prevent human deaths and injuries, but also can prevent very large economic losses. Probably for that reason, fire and explosion prevention has received a great deal of attention from the safety profession.

Finally, this chapter discusses injury prevention programs. Because management has the primary responsibility for prevention of work-related injury and illness, a successful injury prevention program must start with a strong commitment from management. The stronger the commitment at the top, the greater the likelihood of success. The success of one such program is illustrated by a discussion of the injury prevention program of one large company—Du Pont.

Workplace injuries can be prevented by proper design of structures, machines, and operations (see table 6-l). Proper design considers the stresses to be placed on the building structure, the arrangement of spaces for the work to be accomplished, and specific safety requirements. For example, falls on working surfaces, the single most common cause of workplace injuries (13.5 percent of all nonfatal injuries), can be largely prevented by designing proper walking and working surfaces.

Appropriate design, including safe construction plans, can prevent work-related injuries as buildings go up and equipment is installed. Structure collapse during concrete pouring may kill or injure a number of workers at once. Such catastrophes get media attention whereas the bulk of work-related injuries and fatalities that occur singly do not. One disaster at Willow Island, WV,

Photo credit: Office of Technology Assessment

The rear of this construction site shows the use of shoring to prevent the collapse of surrounding soil

Table 6-1.-Princlples of Preventing Work-Related Injury

Injury-prevention objective	Examples	Relevant control principle
1. To prevent the creation of the hazard.	One-story buildings reducing need for ladders	Elimination, substitution
2. To reduce the amount of hazard.	Reducing speeds of vehicles.	Process design
3. To prevent release of the hazard.	Bolting or timbering mine roofs.	Enclosure
4. To modify the rate or spatial distribution of release of the hazard.	Brakes, shutoff valves, reactor control rods.	Ventilation
5. To separate, in time or space, the hazard and that which is to be protected.	Walkways over or around hazards, evacuation.	Isolation Administrative controls
6. To separate the hazard from workers by interposition of a material barrier.	Operator control booths.	Isolation, Personal protective equipment
7. To modify relevant basic qualities of the hazard.	Using breakaway roadside poles, making crib slat spacing too narrow to strangle a child.	Process design
8, To make what is to be protected more resistant to damage from the hazard.	Making structures more fire- and earthquake-resistant.	Process design
9, To counter the damage already done.	Rescuing the shipwrecked, reattaching severed limbs, extricating trapped miners.	NA
10. To stabilize, repair, and rehabilitate the object of the damage.	Posttraumatic cosmetic surgery, physical rehabilitation, rebuilding after fires and earthquakes.	NA

SOURCE: (71,197).

in 1979 was found by the Occupational Safety and Health Administration (OSHA) and National Bureau of Standards investigators to be related to concrete failure from improper pouring and from insufficient allowance of curing time. The National Institute for Occupational Safety and Health (NIOSH) (584) is refining equations to predict more accurately concrete's curing time as an aid to preventing similar disasters.

In 1981, 11 workers were killed and 23 injured in Cocoa Beach, FL, when a five-story building collapsed during placement of a concrete roof slab. Analysis of this catastrophe showed two factors caused the failure:

- A design error: a check for punching shear (the stress or force around holes cut in beams) was omitted.
- A construction error: supports for reinforcing steel other than those-specified by the design were used and proved to be inadequate.

A failure at one column precipitated a progressive failure of the slab, which, when it fell, caused successive collapse of all lower floors (271). Tragically, this disaster closely resembled a collapse of similar construction in Jackson, MI, in 1956.

Information about these and other failures is now available in a data base maintained by the University of Maryland's Architecture and Engineering Performance Information Center. This computer compilation of analyses of design errors enables designers and engineers to search for and compare information on failures of similar designs.

Checklists have been developed for engineers, architects, and designers to guide their attention to methods of reducing injury risks. An abbreviated example of such a list is given in table 6-2.

Codes and standards for building structure, for steam, heating, and electrical systems, and for fire and injury prevention are also used as design criteria. The sources for these codes include the American National Standards Institute, the National Electrical Codes, the National Fire Protection Association (NFPA) Codes, OSHA regulations, and recommendations made by NIOSH.

Site planning and plant layout for location of buildings, facilities, and processes and other design practices can be done in ways to prevent work-related injury. Table 6-3 provides examples of injury control practices that are possible

Table 6-2.—Prevention Checklist To Be Used Before Starting a Production Plant

Section I—Boiler and machinery review
- A. Boilers
- B. Pressure vessels
- C. Piping and valves
- D. Machinery

Section n-Electrical safety review

Section Ill—Fire protection review

Section lV—Personnel safety review
- A. Project site location
- B. Building and structures
- C. Operating areas
- D. Yard

Section V—Process safety review
- A. Materials
- B. Reactions
- C. Equipment

Section Vi—Environment control audit
- A. Atmospheric discharges
- B. Liquid discharges
- C. Solid discharges

Section VII—Periodic plant loss prevention review (manufacturing) to:
- A. Keep operating personnel alerted to the hazards.
- B. Determine whether operating procedures require revision.
- C. Carefully screen the operation for changes that may have introduced new hazards, or changes that should be made to reduce existing hazards.
- D. Reevaluate property and business interruption loss exposures.
- E. Uncover potential hazards not previously recognized, especially in the light of experience or new information.

SOURCE (172)

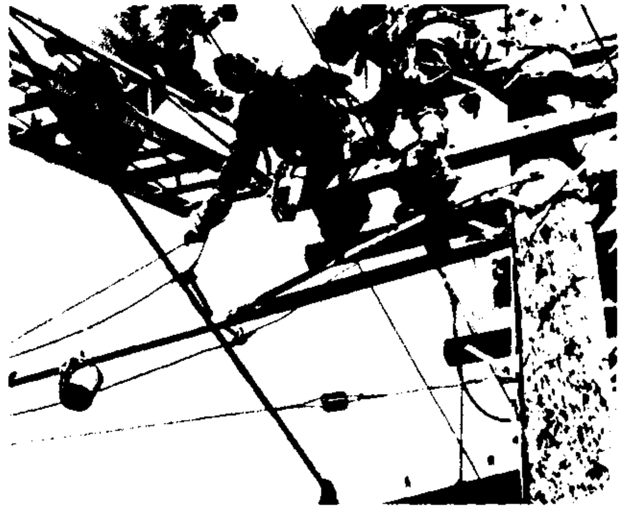

Photo credit: Department of Labor, Historical Office

Electrocutions account for about 6 percent of reported work-related fatalities

through plant layout. The isolation of hazardous materials and machinery, for instance, can be achieved through building special rooms or buildings. Falls can be prevented by providing adequate walkways and lighting. Again, specific codes are available to guide designers and planners in these areas.

Many vehicular-related injuries and fatalities in and around factories maybe prevented through

Table 6-3.—Examples of Injury Control In Plant Layout

Source of injury	Design solutions
Contact with moving machinery	Adequate space between and around machines
Potentially explosive or inflammable processes and substances	Remote siting; separate buildings to contain explosion or fire; isolated storage areas
Crane loads striking worker	Site cranes away from work areas
Building fire	Adequate space between buildings to prevent spread of fire
Chemical burns	Use corrosive-resistant containers, remote siting, and special handling procedures
Falls from trestles	Provide adequately wide walkways along trestles, and adequate lighting
Falls in pits or bins	Provide grating screens and covers, and adequate lighting
Falls on stairs and from ladders	Design stairs with non-slip tread; provide adequate lighting
Electrocution and electrical burns	Adequate grounding; wiring inaccessible to inadvertent insulation wear
Being caught in machinery during maintenance	Interlocks and tag-out procedures to prevent inadvertent start-up
Being caught in machinery during operation	Adequate illumination
Explosion related to broken light bulbs	Special lamps and enclosures where physical conditions may shatter ordinary bulbs

SOURCE (322)

careful planning of transportation facilities, including shipping and receiving departments, railroad sidings, parking lots, and roadways. Worksite roadways and walkways can be laid out and designed according to safe engineering practices to prevent traffic-related injuries. Adequate anticipation of traffic to, from, and during work and landscape design to eliminate blind spots can also reduce risk. Railings on stairs and walking inclines prevent falls.

Shipping and receiving, whether by truck, train, ship, or airplane, pose special potential for work-related injury. Facilities can be designed to reduce overexertion and back injury by providing working surfaces at correct height and allowing room for mechanical lifting devices. Shipping and receiving docks can be isolated to prevent harm from mishap when loading or unloading inflammable, explosive, or extremely toxic substances and from falling objects.

Sensible plant layout, including consideration of headroom, aisle width, and access for maintenance can both lower injury risk and increase productivity (322). Clearly, the risk of injury is reduced by designing work stations that are located away from hazardous areas.

PREVENTING MOTOR VEHICLE= RELATED INJURIES AND FATALITIES

Analysis of injury statistics shows that motor vehicle-related fatalities account for 30 to *40* percent of work-related fatalities and are among the 5 leading causes of work-related injuries (see Working Paper #l). While a good deal of public attention is given to “defensive driving, ” speed limits, collision protection through passive and active restraints, and reducing the number of drunk drivers, little of the industrial injury-prevention literature relates to the occupational use of motor vehicles (40).

An insurance company has prepared a handbook that describes both routine and particular precautions. For example, braking systems on earth-moving equipment, large trucks, and long distance tractor-trailers should be maintained with emphasis on safety rather than mere schedules. Drivers should be properly trained to operate equipment safely under different road and weather conditions. Vehicles used for employee transport should meet appropriate requirements for both driver and passenger safety; for example, proper emergency exits should be available to allow escape.

PREVENTING CONSTRUCTION= RELATED INJURIES

The lost-workday rate from job-related injuries is much higher in the construction sector than the all-industry average. The constantly changing conditions of construction sites create a variety of workplace hazards against which workers must be protected.

Specialized, often large, machines that come and go to construction sites bring their own mechanical energy-related hazards. The “beep-beep-beep” of backing earth-moving equipment alerts workers on the ground; the cages around drivers’ seats protect against falling and swinging objects and from being crushed if the machine tips over. Seat belts or other restraining devices protect vehicle operators from harm during collisions.

A frequently reported cause of injury is falls from heights—31 percent of construction fatalities. These may occur from inappropriate ladders, improperly erected scaffolds, poorly designed temporary stairs, or inadequately protected openings in floors, elevator shafts, and roofs under construction. Yet available equipment and procedures can protect against each of these hazards. Manufactured ladders that meet codes and ladders constructed on the job that meet minimum requirements will reduce the number of falls. Rail-

Photo credit Department of *Labor. Hisforlcal Office*

Earthmoving equipment is now built to include protection from falling objects and accidental rollovers

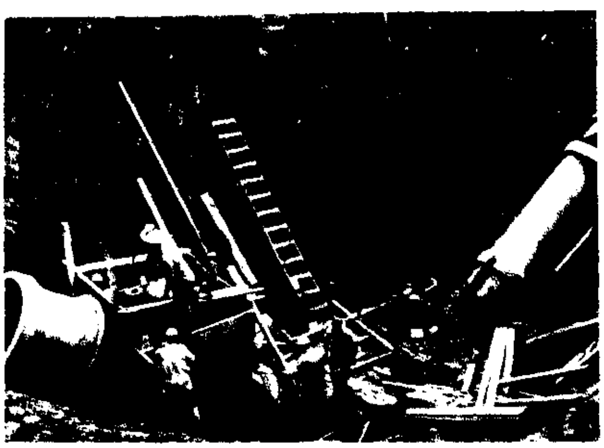

Photo credit OSHA, Office of *Information and Consumer Affairs*

Improperly shored trenches can be a source of serious injury when laying pipes and pipelines

ings that are sufficiently strong and high will prevent a worker from slipping through openings inadvertently. Adequate scaffolds have been described for particular construction tasks; bricklaying and stonework require sturdier scaffolding than light carpentry.

Another source of injuries and fatalities is trenching. Collapsing trenches can bury workers

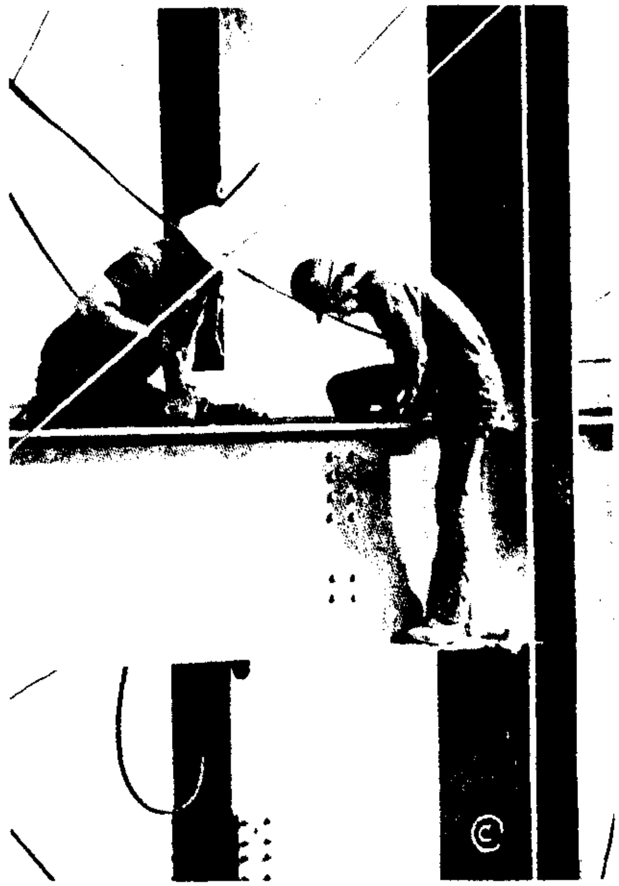

Photo credit: OSHA, Office of Information and Consumer Affairs

Falls from heights are a frequent source of fatal injuries in the construction industry

alive. This can be prevented by shoring trenches or by sloping trench sides as they are dug to prevent collapse.

Scaffolding, railings, and blocked holes in floors under construction are day-to-day steps taken to prevent injury. These temporary measures must be put up, taken down, and supervised each day or as each floor in a new building is completed.

Construction workers depend on personal protective equipment—hard hats, gloves, and steel-toed shoes-for immediate protection but consideration of worksite layout to prevent workers entering areas likely to be filled with **flying objects plays an important role in preventing construction-related injuries and death.**

Photo credit: OSHA, Office of Information and Consumer Affairs

Mechanical power presses are an important safety hazard in many manufacturing plants

In all these cases, the persons responsible for safety must be given authority to require that precautions be taken. The urgency to finish a job and the false confidence that comes with "I've done it a thousand times this way" lead both workers and management to ignore hazards. These human tendencies are among the reasons that involvement of management from the top down is necessary for injury control.

PREVENTING MANUFACTURING= RELATED INJURIES

Though the rates are not as high as the construction industry, the manufacturing sector still has injury and illness rates higher than the all-industry average (see ch. 4 and Working Paper #l). It also offers many opportunities for injury prevention because it is a relatively stable work environment. Workers make products generally using the same methods day after day, while management closely controls the entire operation.

Manufacturing involves applying energy to wood, metals, or other materials to shape them into usable products. Even handtools multiply human muscle forces greatly; the cautionary instructions about hammers, screwdrivers, saws, and snips delivered from parent to child or from teacher to student often include gory descriptions of injuries known first or second hand. Power tools move faster, generate greater energy, and, hence, involve a greater degree of hazard.

The following selected examples of dangerous operations among the wide variety found in manufacturing operations illustrate injuries that may be related to manufacturing and provide a summary of control strategies.

Woodworking Processes

Table 6-4 lists woodworking processes, possible injuries, and preventive technologies. Devices used to cut, shape, and join wood—including a variety of power saws, planers, shapers, lathes, and routers—are capable of causing serious injury, especially to the hand or eye. Preventing such injuries depends on design of special guards, on work practice, and on personal protective equipment. For instance, a guard would prevent contact with a power saw, a lock would prevent the saw from being turned on while maintenance work is in progress, and gloves and goggles would protect the worker's hands and eyes from flying chips.

Many items of equipment can be purchased with built-in guards *(322)*. There is general agreement that built-in guards are less expensive, more

Photo credit OSHA, Office of Information **and Consumer** *Affairs*

Improper use of powered woodworking tools, such as this saw, can lead to serious injuries, including cuts and amputations

effective, and less likely to interfere with production than "bolt-ons." Unfortunately, the extra cost—coming at a time managers are spending money on new machinery-may inhibit purchase of the safer equipment.

Metalworking— Cutting, Welding, and Cold Forming

The most casual sidewalk superintendent can appreciate the hazards inherent in welding and cutting metals. These involve high temperatures, hot metal, and intense visible and ultraviolet light. Table 6-5 shows a summary of the potential hazards of each process and gives examples of the types of control technologies that can be used to prevent injury.

The hazards of welding and cutting are similar. Skin may be injured by infrared, visible, or ultraviolet radiation or by fire, hot metal parts, explosions, or electrical shock. Eye injury or burns may result from flying sparks, hot metals, or the immensely strong light emitted in the infrared, visible, and ultraviolet spectrum. Gases including oxygen, acetylene, hydrogen, and others, usually stored under pressure in special cylinders, may explode, or injury may result from physical handling of the cylinders. Shielding can protect adjacent workers, and face masks can protect the welder (322). One type of welding—resistance welding— is usually done by a special machine that eliminates many sources of injury.

Table 6-4.—Technologies for Preventing Work-Related Injury From Woodworking Machinery

Process, device, or tool	Injury potential	Examples of prevention technology available
Saws	Cuts, amputation, eye damage, projectile wounds, hearing loss	Kickback and hood guards, jigs[a], operating methods, push sticks, maintenance goggles, hearing protectors
Jointers, planers	Hand and finger cuts	Swing guards, hold down clamps, maintenance
Shapers	Hand and finger cuts, projectile wounds	Use of solid cutters instead of knives, maintenance, safety collars, brakes, operating methods, holding jigs[a], goggles
Power-feed planers	Hearing loss, projectile wounds	Isolation, goggles, maintenance, hearing protectors
Sanders	Abrasions, projectile wounds	Guards, goggles
Lathes	Eye and projectile wounds	Goggles, face shields
Routers	Hand cuts	Jigs[a] with handles

[a] Jig—a device for mechanically holding a piece of work in the correct position while working on it

SOURCE (322)

Photo credit Department of Labor, Historical Office

Lack of attention to prevention can result in equipment collapse

Photo credit" OSHA, Off/cc of Information and Consumer Affairs

The hazards of welding include heat, flying sparks, and fumes, as well as infrared, visible, and ultraviolet radiation

Cold forming involves applying great cutting and punching forces to metal. The power of the machines for turning, boring, milling, planing, grinding, and power pressing is a obvious hazard. Table 6-5 also includes a summary of the types of injuries associated with these machines. Cuts, eye injuries, injuries from being caught in the machine, and foot injuries from dropping heavy chucks (devices that hold the cutting tool in place during machine work) are the main problems. Control technology ranges from careful design that considers safety to personal protective equipment.

OSHA and NIOSH studied self-tripping power presses that use presence-sensing devices such as photoelectric detectors and light beams to prevent hands from entering the presses. Use of these devices to activate power presses could increase productivity as compared with the use of two-handed switch activators. Although photoelectric devices for these purposes are ordinarily prohibited by an OSHA regulation, a variance was granted to one company to evaluate the relative degree of injury control among workers using self-tripping devices and those using two-handed switches. Investigations found no significant difference in observed injuries or stress as measured by heart rate, blood pressure, and subjective responses to a questionnaire among the two groups of workers tested (588).

Although the photoelectric devices provide protection equal to traditional methods, and at the same time increase productivity, NIOSH studies have found other innovations less positive. For instance, presence-sensing devices that halt machine operation when a worker's hand interrupts a radiofrequency field in the danger zone proved inadequate for reliable injury prevention. These studies have also shown that the current standards for two-handed activator switches for power presses may be inadequate. Under some condi-

Table 6-5.–Technologies for Preventing Work. Related injury From Metalworking Machinery

Process, device, or tool	Injury or illness potential	Examples of prevention technology available
Welding and cutting	Shock trauma; eye injury; back injury from handling heavy gas cylinders; cuts from sharp edges on finished work; hearing loss	Careful layout of equipment, process, and job; arc and spark-shielding; proper insulation of electrical cable; goggles; welding hoods; welders' helmets; gloves; ultraviolet-energy-resistant clothing
Metalworking machinery; turning machines; boring machines (drills, boring mills); milling machines (saws, gear cutters, electrical discharge—EDM[a]); planing machines	Eye injury (flying chips), scalping (hair caught in machinery), foot injury from dropped chucks; hand, finger, or limb injury; skin irritation (cutting fluids), electrical shock (EDM[a])	Machine design, including shielding, proper electrical insulation, local exhaust ventilation for grinding wheel discharge and for discharge gases from EDM[a] machines, provision of emergency stop buttons Safe working practices, including keeping tools sharp, never leaving machine unattended, using handtools instead of hands to work metal
Grinding machines		Inspection of grinding wheels for integrity and balance; good maintenance; shields to prevent flying chips; use of personal protective devices, including goggles, hearing protectors, closely fitted clothing, haircaps, safety shoes
Power presses; hand- or foot-operated presses; metal shears; press brakes	Finger or hand amputation or injury; finger punctures; fatigue; eye injury, foot injury; lacerations	Enclosure of the die during operation; adjustable, fixed, or interlock press barrier guards; point-of-operation safe-guarding with movable barriers, two-handed tripping devices, presence-sensing devices; semiautomatic feed systems to avoid use of hands; electrical controls such as interlocks, emergency stop switches, and ground fault protection; apparatus for transferring dies; anti-repeat clutches and magnetic brakes to prevent inadvertent triggering of power press or shear; frequent machine inspection; careful maintenance; special handtools for feeding pieces into the machine

[a] Milling by electric arc
b Systems for Preventing inadvertant machine operation during maintenance

SOURCE (322)

tions workers could activate the power press and have time to reach into the press before the press ram completes its cycle (588).

Metalworking—Hot Working

Hot metal work is done primarily in foundries. It is characterized by massive, often older, machinery. The size of the operations and the weight and heat of the materials being worked result in many injuries. The processes range from handling raw material—ore concentrates, coal, coke—to working with heating and shaping ovens and production equipment, to non-destructive testing of finished products. Injury risk is high to the eye, head, foot, trunk, and limbs.

Injury prevention depends on proper design of the job, good work practices, and personal protective equipment (table 6-6). Bums are prevented by spark shielding, special clothing, and insulation of electrical cables. Electric shock prevention methods include shielding, guarding, good work practices, proper electrical insulation, and maintenance. Eye protection is needed where sparks and hot metal particles may fly. Fire and ultra-

Photo credit: Department of Labor, Historical Offlce

This machine will not operate unless both of the operator's hands are on the control switches. The use of "two-handed controls" represents one method of preventing injuries associated with power presses and shears

violet-energy-resistant clothing is important for worker protection. Gloves are needed to protect hands from bums. Welders' helmets are required for electric-arc welding.

Preventive Maintenance

Careful attention to the plant, its operations, and workers is necessary to maintain controls. Table 6-7 shows a range of maintenance operations required to prevent injury in manufacturing operations. Maintenance of everything from foundations and footing to electric bulbs can prevent injuries.

Table 6-6.—Technologies for Preventing Work. Related Injury During Work with Hot Metal In Foundries

Process, device, or tool	Injury potential	Examples of prevention technology available
Handling of materials such as sand, coke, and coal	Injury from electrical shock, heat, being struck by or against, or being caught between; explosions, vibration, noise; injury to hand and foot, eye, trunk, limbs, or other body parts; death from trauma or asphyxiation	Ladles equipped with automatic safety locks or brakes; devices to warn when ladles are being moved; appropriately guarded conveyors for transport of sand and molds
Cupolas, crucibles, ovens		Mechanical devices for charging cupolas; blast gates to prevent injury from gas explosion
Production equipment		Venting molds to prevent explosions; two-hand controls for molding and core-blowing machine operators; dust-tight sandblast rooms; guards, two-handed tripping controls for forging hammers, presses, and upsetters; careful and frequent equipment inspection Personal protective equipment, as required, including hard hats, gloves, leather aprons, steel-toed shoes, metatarsal guards, safety glasses, goggles, flame-retardant clothing; devices to prevent doors and other movable parts from hitting workers; material-handling devices to eliminate heavy lifting and possible spills or splashes of solids and liquids

SOURCE (322)

Table 6-7.—Technologies for Preventing Work-Related Injury Through Maintenance of Structures

Process, device, or tool	Injury or illness potential	Examples of prevention technology available
Foundations	Injuries and fatalities from building collapse	Check for and repair settling footings and columns, cracked foundations
Structural members, walls, floors, roofs, and canopies	Injuries and fatalities from plant building collapse	Check for and repair settling walls, defective columns, joists, beams, and girders; cracked building materials such as steel, concrete, wood; cracked walls and windows; sagging or rotted roofs and ceilings; rotted, sagging, cracked floors
Stacks, tanks, and towers	Injuries and fatalities from structural collapse; asphyxiation and acute poisoning from tank gases; injuries from explosions during tank cleaning or repair	Place railing around edges of platforms; check structural integrity; use proper procedures for maintenance work
Platforms and loading docks	Injuries from slips and falls	Use metal protectors on edges of concrete platforming; check surfaces for rotting, holes, or other hazards
Sidewalks and driveways	Injuries from slips, falls, or collision with moving vehicles	Repair damaged sidewalks and motorways; install and maintain warning signs and markings
Underground utility repair and maintenance	Injuries and fatalities related to sewer gas explosion; asphyxiation from oxygen depletion; injuries or fatalities from collapsed trenches; drowning or injury from failure of underground pipelines	Test for gases and oxygen deficiency before attempting maintenance work in underground tunnels and sewers; provide contaminant-free ventilation during maintenance work; slope trenches at angles to prevent collapse
Lighting systems	Cuts from broken bulbs; injury from electric shock, fails, or poor illumination	Provide proper equipment for disposal of burned-out lamps; use properly designed ladders and platforms; clean and replace burned-out bulbs on a regular schedule
Stairs and exits	Injuries from slips and falls; injuries from crowding in emergency situations	Install and maintain adequate handrails, illumination, and walking surfaces on stairs; keep passageways and stairs free for exit; install unobstructed exit doors for fire and emergencies
Grounds maintenance	Injury from grounds maintenance; cuts from mower blades and snow throwers; eye injury from frying objects; collapse from quick-acting pesticides	Maintain tools and equipment; provide guards for belts, chains, and other moving parts

SOURCE: (322)

FIRE AND EXPLOSION PREVENTION

Fire and explosions levy an enormous cost on industry and continue to cause many deaths and injuries among workers and the general public. Of fire-related deaths, 75 percent are due to inhalation of smoke and toxic gases and the other 25 percent to direct flame. Injury and death from fires can be prevented by proper design and construction of buildings, vigilant inspection, early detection and warning, and appropriate control methods.

Building designers play an important role in fire prevention. Engineers and architects can anticipate fire problems in the design of buildings and facilities and thereby protect workers and the public from injury. A study of over 25,000 fires between 1968 to 1977 resulted in a listing of ignition sources ranging from the most common—electrical ignition and arson—to the least common—lightning (table *6-8).* These findings point to areas where controls are most needed and on

Photo credit OSHA, Office of Information and Consumer Affairs

The hazards of hot metalworking are found in steel mills and foundries

Table 6-8.—Common Ignition Sources of Industrial Fires

Source	Frequency (percent)	Means of prevention
Electrical	22	Design and maintenance
Incendiarism (arson)	10	Security
Smoking	9	Supervision, substitution
Hot surfaces	9	Design and maintenance
Friction	7	Design and maintenance
Overheated materials	7	Work practice and control
Cutting and welding	7	Work practice
Burner flames	6	Design and maintenance
Spontaneous ignition	5	Housekeeping
Exposure (fire from adjacent property)	4	Design
Combustion sparks	3	Design
Miscellaneous	3	Design and other
Mechanical sparks	2	Housekeeping
Molten substances	2	Work practice and maintenance
Static sparks	2	Design (grounding)
Chemical action	1	Work practice
Lightning	1	Design (grounding)

a Removal of chemicals that cause cigarettes to burn for longer times would reduce the number Of cigarette-caused fires that kill 3,000 Americans annually.

SOURCE: (322).

Photo credit OSHA Office of Information and Consumer Affairs

An explosion at this oil refinery killed 3 workers and injured 14 others

which building codes and standards tend to concentrate for prevention.

Local building codes and OSHA standards, generally based on National Fire Protection Association Codes, provide the minimum basis for fire-safe construction design. The NFPA Life Safety Code is an appropriate design guide for warning and exit requirements.

Since electrically started fires are the most frequent type, appropriate sections of the OSHA standards and the National Electrical Code of the NFPA are to be followed for proper installation and maintenance of electrical equipment. Sparking can occur when unwanted metal objects enter machinery. Particular attention should be given to preventing heat-generating short circuits and arcs, two of the leading causes of electrical fires. Temporary and makeshift wiring when existing electrical outlets are overextended to accommodate a growing office computer system, for example, is one potential source of fire. Improperly insulated portable electric tools and extension cords should be avoided. Proper grounding is essential for preventing electrical shock and fire-causing arcing.

Smoking, friction, and open flame devices are other sources of work-related fires that can be controlled. Smoking should be prohibited in all but approved areas to prevent fire. Friction from improperly maintained machinery can cause fires. These can occur in workplaces where organic dust may accumulate, such as grain elevators, textile mills, and woodworking mills. Open flame devices used in industry are frequent causes of fire, These include heating torches and welding and cutting equipment. Many fires occur in plants where housekeeping is lax. Accumulations of oily rags, waste, and other combustible refuse can ignite unless kept in air-tight noncombustible containers. Compliance with local ordinances concerning incineration, sewage, and other means of waste disposal provides a minimum of safety.

A designer, engineer, manager, *or worker* who knows the identity of combustible hazards can choose the proper emergency equipment to deal with fires. Table 6-9 is the fire classification developed by the National Fire Protection Association that relates to the decal identifying most fire extinguishers. Clearly, placing the appropriate extinguisher in the right place is necessary.

Giving early warning of fires, extinguishing a fire at early stages, and quickly clearing buildings are also obviously essential to prevent injury. Design should include early warning and alarm sys-

Table 6.9.—National Fire Protection Association Fire Classification

Class	Description	Means of control
A.	Fires occurring in ordinary material such as wood, paper, etc.	Cooling and quenching by water to reduce heat is recommended. Special dry chemicals may be used to control flame.
B.	Fires that occur in the vapor-air mixture over **the surface of flammable liquids** such as gasoline, oil, etc.	Since water tends to spread such **fires, dry chemicals, carbon** dioxide, foam, or halogenated agents are preferred.
C.	Fires that occur in or near equipment using electrical energy.	Non-conducting agents such as dry chemical or carbon dioxide must be used to extinguish to prevent electric shock.
D.	Fires that occur in combustible metals such as magnesium, lithium, potassium, etc.	Since ordinary means of control such **as** water may increase the intensity of such **fires, special equipment and materials are required to control this type of fire.**

SOURCE (322)

terns. Both manual and automatic fire extinguishing systems should be strategically located to limit fires in their early stages. Fire-safe stairwells, adequate aisle space, and appropriate stairwell width are essential for safe and rapid exit. Emergency stairwell lighting should be provided.

The use of fire-resistant materials, the design and construction of building frameworks, ventilation systems, concealed spaces, storage areas, exteriors, fuel sources, and building uses—all part of the designer's functions—make a difference. Widespread use of masonry in the interiors of European dwellings is thought to be a factor in their superior fire record. Plastic interiors used in this country, on the other hand, are the source of deadly toxic gases during fires.

Explosions are a special preventive concern of designers. Explosive atmospheres result from the accumulation of organic dusts and from gases and vapors. The U.S. Department of Agriculture lists 133 dusts by degree of explosibility (322). Dusts produced from phenolic, urea, vinyl, and other synthetic resins and powders used in the plastics industry also explode under certain conditions. The Explosion Venting Guide of the NFPA provides specifications for buildings where the risk of explosion is high.

Explosion prevention can be accomplished by inert gas systems that displace oxygen so that gases and dusts are incombustible and by adequate ventilation, proper process operation, and vigilant maintenance. Gas lines and valves should be inspected frequently for leaks.

Since three-fourths of fire-related deaths are from toxic fumes and since industrial fires may involve extremely toxic materials, it is important for firefighters to be able to identify chemical and material inventories in establishments under their jurisdiction. Several municipalities and States have developed systems for this. The OSHA hazard communication (labeling) standard may also be useful for this purpose.

INJURY CONTROL PROGRAMS IN INDUSTRY

Effective control of work-related injury depends in part on how well a company is organized to deal with it. Management has the primary responsibility for prevention. Relevant programs include training workers, supervisors, and managers to recognize workplace hazards and take steps to control them (see ch. 10).

Successful injury prevention must start with a strong commitment from management. The stronger the commitment at the top the greater the likelihood of success. Typical management programs for preventing work-related injury (and illness) include:

- establishing clearly stated company policies for prevention;
- avoiding work-related injury and illness by planning ahead when designing new plant or modifying existing processes;

- analyzing each hazardous operation to determine the steps required to do the job without causing injury or illness;
- identifying hazards through workplace surveys and investigating the factors surrounding an event that caused or nearly caused injuries or illnesses;
- maintaining accurate and complete records of the causes of injuries and illnesses;
- training workers, supervisors, and managers to identify hazards and prevent injury and illness that could result from them; and
- placing and maintaining people in jobs suitable to their physical status.

THE DU PONT INJURY CONTROL PROGRAM

Perhaps the best source of information about how to run an injury-control program is available from the successful companies. Determining one best program is impossible, of course, for hazards vary from industry to industry, plant to plant, and department to department, making comparisons of overall rates difficult. This section focuses on the Du Pont Company not because its program is best, but because it is good enough that Du Pont sells it to other companies and much information is available about it. Du Pont plants have very low injury rates, which have dropped dramatically since 1912, falling even more than the all-industry average according to National Safety Council data. A key to the company's success in preventing injuries at work is its commitment in this area. Its program consists of four main parts:

- establishing injury prevention as a top management objective;
- establishing injury prevention as a line-management responsibility;
- adopting an injury-control philosophy to guide management action; and
- establishing an organization for injury control.

Du Pent's success in preventing injuries may largely be attributed to strong commitment of top management. The founder of the company was personally committed to preventing injury among his workers, often family or friends, who were in the high-risk business of manufacturing gunpowder.

Commitment to injury prevention still permeates this *Fortune 500* corporation from the top down. For example, performance rating at all levels of management is partly dependent on success in preventing injury. Du Pont lists the following as incentives for making injury control a management objective:

- protect workers,
- improve profits,
- improve product quality,
- improve productivity,
- improve employee-management relations, and
- comply with OSHA regulations.

Du Pont finds that injury control increases profits. Using National Safety Council statistics for 1976, Du Pont estimated the average cost of each disabling injury to be $7,182. The company then compared its estimated costs for 1977 (based on their rate of 0.2 disabling injuries per million hours worked) with the projected cost if the rate had been at the all-industry level of 10.87. Table 6-10 shows Du Pont's estimated savings were greater than $15 million, based on the all-industry injury rate; a more representative comparison, however, would be with large chemical companies, which as a group have lower injury rates than the all-industry average. Nevertheless, Du Pont's own comparisons were impressive enough to be featured in a ***Fortune*** article about savings from preventing work-related injury (284).

Line-management emphasis on preventing injury is another critical element of success. Responsibility for preventing injury is as much a condition of employment in Du Pont as getting the job done, High-level staff meetings often begin with reports of job injuries, and any fatality has first priority at any management meeting, including the presidents.

Table 6-10.–Du Pent Calculations of Cost Savings From Injury Control

	Du Pont U.S.A. actual (1977)	Totals if at all industry rate (1976)
Disabling injuries/million worker-hours	0.20	10.87
Disabling injuries/year		2,174
Average cost/injury	$7,182	$7,182
Cost/year (total injuries)	$287,280	$15,613,668

SOURCE: (156)

Five basic beliefs underlie Du Pont's program:

- **all personal injuries can be prevented,**
- **managers and supervisors must personally accept their responsibilities to prevent personal injuries,**
- **reasonable safeguards are possible for all construction and operating exposures that may result** in injury,
- efficiency and economy are enhanced when personal injuries are prevented, and
- all employees must be trained to understand the advantages to them, as well as to the company, of taking responsibility to prevent personal injuries.

Du Pont's Safety Training Observation Program (STOP) uses programed self-study courses to enhance injury prevention. It is one of more than 200 vocational courses developed for industrial craft skill training. The objective of STOP is to train line managers to notice workplace conditions that might lead to an injury or illness.

STOP presents seven broad categories that are suggested for observation rather than having detailed checklists of hazardous working conditions. The manager looks for injury potential associated with procedures, tools, equipment, orderliness, personal protective equipment, positions of people, and actions of people. **A** training unit divided into eight parts is used for instruction and includes pocket-size cards to record workplace observations as practice between teaching units.

The administrator of the course is key to its effectiveness. To show management commitment to the course and to motivate supervisors to be equally committed, the administrator must be highly placed in the management structure.

The desired outcome of the training, which should take only 12 to 16 hours away from work, is supervisors who are able to recognize hazardous conditions, to assign responsibility for correcting it, and to ensure the elimination of the hazard. The success of the program has been measured through reduced injury rates in firms that have purchased and used the training program from Du Pont.

SUMMARY

Perhaps because of the more obvious sources of injury as compared to illness, safety engineering appears to be more pragmatic than industrial hygiene. Engineers have, to some extent, directed their attention to sources of hazard such as electricity, falls, and fires, and produced codes and standards for good practice.

These codes and guides to good practice appear often to be based on the personal experience and judgment of the practitioners who happen to write safety textbooks or are members of the committees who write the codes. This field has relied on experience and judgment instead of scientific analysis, systematic data collection, the application of epidemiologic techniques, and experimental research. It is probably fair to say that up to the present there has been little that might be called a "science" of safety. In addition, as described in chapter 4 on the identification of injury hazards, the attempt to attribute most injuries to so-called unsafe acts has often diverted attention away from the design of plant and equipment that can prevent "unsafe acts" or minimize the adverse consequences of "unsafe acts. " However, it is unclear what differences a more theory-based rather than the pragmatic approach would have made.

Several specific areas where injury control can be applied were discussed in this chapter. A number of different methods and technologies are available for preventing injuries related to motor vehicles, construction activities, manufacturing processes, and fire and explosion hazards. These include the proper planning of plant sites and the design of equipment, as well as the use of guards, personal protective equipment, and appropriate work practices. Adequate attention to preventive maintenance, and the training of workers and managers, also play roles in injury prevention. Successful injury *control* programs start with a strong commitment *to* injury prevention at all levels of management.

Controls are known for many hazards. However, they are not always used because they were not built into a plant, are not available at a particular worksite, or are pushed aside to get the job done. All of these reasons for not using controls emphasize the important role of management in providing controls and seeing that they are used.