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HUMAN FACTORS ANALYSIS

OF

MATERIALS HANDLING EQUIPMENT

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Human factor deficiencies in the design and operation of powered industrial trucks, powered cranes and hoists, and powered conveyor sytems were evaluated. Information concerning the major categories and causes of accidents involving materials handling systems was furnished by Wisconsin workers' compensation case histories, accident investigations, and employee reports of injury. The Wisconsin data was supplemented with new information gathered from on site observations of the actual equipment in use. Specific design deficiencies were not as critical in causing accidents as were deficiencies in proper applications of the equipment, inadequacies in the use of accessory tools and equipment, and general management and system inadequacies in the development and exchange of relevant information concerning hazards and proper equipment use. The authors conclude that the hazards of industrial materials handling systems are not managed properly, resulting in uncontrolled hazardous conditions and behaviors that produce injuries and illnesses. The authors recommend that improvements be made in standards for equipment and its utilization, and that further research be conducted.

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ABSTRACT

Powered industrial trucks, powered cranes and hoists, and powered conveyors were the subjects of a study of safety in the design and use of material handling equipment. Possible human factors deficiencies in the design, operation and application of these equipment types were the specific issues addressed by the research.

Wisconsin Worker's Compensation case histories, accident investigations, and employee reports of injury furnished major categories of accidents and causal factors. These in turn were validated, refined, and new information added, through site-visit observations of the actual equipment in use.

Specific design deficiencies were not found to be as critical as were deficiencies in proper applications of the equipment, inadequacies in the use of accessory tools and equipment, and general management and system inadequacies in controlling material handling hazards through the development and exchange of relevant information as to hazards and proper equipment use. Recommendations are included for possible standards improvement and for further research.

This report was submitted in fulfillment of Contract No. 210-76-0115 by the Wisconsin Department of Industry, Labor and Human Relations under the sponsorship of the National Institute for Occupational Safety and Health.

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Cooperation from Wisconsin employers, manufacturers and dealers in materials handling equipment was the key factor in the success of this project and is greatly appreciated. Special thanks are due to the numerous workers, supervisors, managers and safety directors who contributed their time and expertise during the site visits. We are indebted also to the members of the International Standards Organization, Technical Committee 110, Subcommittee on Powered Industrial Trucks, for their interest and encouragement.

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SYNOPSIS

This section presents in a broad but concise form the main issues addressed by this study and the major directions indicated for further action. The more specific and detailed findings and recommendations are included in each of Chapters 4, 5, and 6.

OBJECTIVES AND METHODS

In very general terms, the purpose of this study was to uncover, through data analysis and field observations, possible human factors deficiencies in the design and operation of powered industrial trucks, powered cranes and hoists, and powered conveyor systems. Objectives of the analysis included suggestions for improvements in the Federal standards governing the equipment types, and suggestions for alternative means and counter-measures for dealing with the hazards associated with the equipment studied.

Major accident categories and causal factors were obtained from data analysis of Worker's Compensation records, accident investigation reports, and employee reports of injury or illness. These patterns served as the basis for later discussions, site visit observations, and final analysis of results.

Twenty-four industrial firms contributed to the study, either in furnishing data and discussing material handling hazards, or in opening their plants to an observation visit. A team of researchers, including one of the two human factors consultants to the project, usually completed such visits within one day.

The details of the site-visits, including the comments of those workers, supervisors and management personnel who provided information on hazards, were correlated with the accident patterns and findings from the data analysis. When the gathering of information was completed, a systems analysis of the human factors involved in designing, operating, and managing materials handling equipment was carried out.

RESULTS

The results of the research are summarized here, first in terms of general findings, often common to all materials handling equipment types, and second, as specific problems associated with cranes, conveyors or industrial trucks.

General Findings

(1) Design features of industrial trucks, cranes, and conveyors, of both old and new models, cannot be clearly implicated as primary accident-producing factors. The most striking characteristic of the accidents and hazards studied is the multiplicity and variety of causes and their interactions, both behavioral and physical, of which equipment design is but one part.

(2) Contributing factors to the development of hazards and accidents in this area arise from a spectrum of people, industrial equipment, management practices, and industrial and governmental policies and standards. For the equipment studied, these include designers and manufacturers of such equipment, dealers in both equipment and accessory tools, management personnel including equipment purchasers and specifiers, design engineers, plant layout specialists, industrial engineers, plant managers, supervisors and workers. Decisions regarding design, selection, application, operation, and maintenance of the equipment, and decisions regarding safe practices, preventive measures, and worker training too often appear to be made without adequate information, research, or feedback from others involved.

(3) These findings lead to the conclusion that the hazards of industrial trucks, conveyors, and cranes are not being managed. On the establishment level, the result is uncontrolled hazardous conditions and behaviors combining to produce injuries and illnesses. But on a broader scale, it is the lack of attention to influences and factors arising outside the establishment that constitutes the problem of unmanaged hazards: considering the spectrum of businesses, institutions, government agencies and other groups with a potential positive impact on material handling safety, it appears that the lack of integration of efforts between such change agents, and the failure to define and set joint responsibilities and objectives in the safety and health area, is perhaps the most critical finding of this research.

Results specific to the three equipment types studied can be summarized as follows:

Powered Industrial Trucks -

(1) The ergonomic or traditional human factors design features of these trucks cannot, on the basis of this study, be considered primary factors in the development of industrial truck hazards and accidents in general, nor can such features be dismissed from attention. While numerous factors and variations were found to contribute to the problems at least as much as design features, significant design weaknesses involve inadequate safety devices, visibility factors, variations in the activating means for service brakes on stand-up rider trucks, cramped driver compartments, and hard seats lacking support for the lower back and thighs.

(2) In the plants visited during this study, two dominant facts emerged: the majority of industrial trucks in use were surprisingly old, and a key factor in the operational hazards discussed was a lack of maintenance on these trucks. Truck malfunctions, often inevitable results of physical age, and often preventable through preventive maintenance, were cited as main factors of a number of hazards.

(3) Industrial truck operator selection and preparation, job design, and workplace layout are crucial factors governing hazards in this area. Operators often had adequate experience, but little or no training; available training appeared to be inadequate in preparing operators for the unexpected, unplanned conditions and behaviors which underlie the majority of hazards. While injuries to pedestrians were a major result of the data analysis, site-visit results revealed little attention to factors of communication between the truck operator and pedestrian co-workers or others sharing the same area.

Powered cranes and hoists -

(1) The operator of the crane or hoist, whether overhead, mobile, or pendant-operated, is the key person responsible for safe lifting operations. If management supplies the proper resources and maintains the equipment, the operator can control, more than the hitching or floor personnel, the minute-to-minute hazards involved in heavy lifting and moving. The operator, depending on personal abilities, experience and training, can compensate for a number of deficiencies, including inadequate attachments of the load, and some mechanical inadequacies, in the operation of the crane or hoist itself.

(2) The main hazard in crane and hoist use uncovered by this study is the threat of a load falling due to insufficiently attached loads. While the attachment of the load is primarily the responsibility of the hitching crew in overhead operations, factors affecting the attachment system involve designers, manufacturers, dealers, training personnel, maintenance, and the operator, among others.

(3) Among crane or hoist factors directly influencing safety, malfunctions during lifting were found to be significant. These include any unreliable or inconsistent modes of operation, including jerking or slipping of the hoist means, and inadequate or un-smooth braking. Such factors could often be traced to insufficient attention to machine maintenance.

Powered conveyor systems -

(1) The predominant injury associated with conveyors involves workers or maintenance personnel getting caught in the moving parts of the system. Contributing to the problems in this area were instances of inadequate or disabled machine guards, and poor location of start-stop controls.

(2) Conveyors are involved indirectly in several categories of accidents: employees are struck by material being conveyed, they are injured by falls near conveyors when the latter produce wet floors, and workers suffer overexertion-types of injuries in manually handling conveyed goods. Conveyor height and accessibility, and the relationship of the conveyor to workplace layout and job design are key factors here.

RECOMMENDATIONS

Summarized here are recommendations for action directed at NIOSH, the materials handling industry, and employers responsible for managing the hazards of the equipment studied.

Five general recommendations are addressed to the issues common to the three equipment types:

(1) The integration of industrial, government, and worker resources for improved safety and health in materials handling calls for the development of improved hazard and accident data and a free exchange of such information between manufacturers, dealers, users, government agencies and others.

(2) Performance standards for preventive hazard management are needed to complement OSHA regulatory standards. The behavior of humans in operating and managing materials handling equipment needs to be incorporated into safety and health practices along with the primarily physical specification standards of OSHA.

(3) A Federally-sponsored and subsidized Materials Handling Safety & Health Research Institute is needed to investigate and develop countermeasures for the operational hazards of industrial truck, crane and conveyor use.

(4) NIOSH research programs in the human factors and system management of materials handling hazards are recommended in these areas:

(a) Hazards, accidents and injuries discussed in this study need to be correlated with the work-process variables of change, of unexpected and unplanned events and variances, and of job design.

(b) Operators and workers using cranes, conveyors, and trucks need improved means of communicating and of being informed of hazards for more effective, continuous control over equipment safety.

(c) Safety and health managers using materials handling equipment need research to develop better instruments for efficiently detecting, tracking and abating hazards as they arise, and human factors systems principles are needed for analyzing and assessing the causes and factors of hazards and injuries.

(5) Hazard management should be integrated into the management of all plant activities and functions. Top management commitment has been shown to be a characteristic of safe plants, but the separation of safety and production managements should be reversed for a total organizational commitment.

For each equipment type, the major recommendations are summarized as follows:

Powered Industrial Trucks:

(1) NIOSH research programs are needed to better determine how various truck design and workplace factors affect sensory information needed by workers, information overload, and feedback compliance of machine operations. Other research topics include the effects of worker participation and

involvement in decisions affecting truck safety, and research designs for evaluating the safety and health effects of ergonomic improvements.

(2) OSHA standards for industrial truck operations and for operator training need revision. Specific guidelines are needed for employers to ensure their compliance with standards pertaining to training, and training should be extended to include pedestrians and others working near rucks. Compliance officers need improved education in forklift truck operations, in utilizing available plant data on trucks and truck hazards, and in relying on the expertise of plant personnel for improved detection of hazards.

(3) A Task Force to develop incentives in industry for updating old industrial trucks is called for.

(4) The Bureau of Labor Statistics, U.S. Department of Labor, should develop a nation-wide information system, based on the Supplementary Data System, geared toward identifying industrial truck hazards and evaluating the effects of countermeasures and inspections.

(5) Manufacturers need to increase their research and development efforts in the human factors and ergonomics design areas of industrial truck operator visibility, the operator's compartment, pinch-points, and mounting/dismounting means for sit-down rider trucks.

(6) Manufacturers, dealers, and users need to develop better means of obtaining and exchanging data on hazards, accidents and injuries involving industrial trucks.

Powered Cranes and Hoists:

(1) Crane operators, especially in overhead and mobile crane operations, should be recognized as the key people responsible for lifting safely. They should be given all necessary resources, including adequate training, experience, management support, comfortable working conditions, and a properly functioning machine.

(2) Personnel involved in attaching loads to the crane need to have detailed knowledge of proper attachment tecnniques, training and education, and all of the resources necessary to ensure safe attachments, including readily available lifting accessories and attachments in good condition.

(3) Management must ensure that the proper attachment accessories are available, and that this hardware is in good repair, is inspected regularly, and is used in a safe manner. A critical need is the proper availability of lifting hardware, so that selection of correct attachments can be made as required for lifting and transporting different loads.

(4) Cranes and hoists need continuous preventive maintenance to ensure smooth operating condition.

(5) Proper application - the matching of the lifting device to the load being lifted and the movement required - needs to be recognized as a key problem in the development of operational hazards and accidents.

(6) Managements can reduce hazards and accidents by adhering strictly to the OSHA standards relating to crane utilization and sufficiency. Existing standards should be complied with and expanded upon to meet the demands of the specific tasks.

Powered Conveyors:

(1) Worker input regarding the following design features should be considered by manufacturers and conveyor users: location and layout should minimize reaching, uncomfortable standing positions, and improper heights for lifting tasks; noise should be reduced to allow worker communication in emergencies; and adequate lighting and non-slip floor surfaces should be provided.

(2) The guarding of pinch points, placement and design of emergency stop controls, and lock-out systems for conveyor maintenance are critical needs for controlling conveyor hazards.

(3) Job design, including the selection of tasks to be done by the worker and the consideration of worker skills, training, experience and communication needs, must incorporate the human factors of both the technology and the behavioral components, or socio-technical considerations.

(4) NIOSH can initiate research projects for conveyor safety in these areas:

(a) Research and technical support for behavioral performance standards development.

(b) Worker input in conveyor design for safety and health should be studied and evaluated.

(c) Checklists for design and operation should be developed based on research.

(d) Training of people doing conveyor-related jobs should stress preparation for variances and coping with unusual events.

CHAPTER 1. INTRODUCTION

Safety in the design and use of tools, equipment and machines has received increasing emphasis over the least several years, particularly since the advent of the Occupational Safety and Health Act of 1970. But injuries involving these items have persisted. In June 1976, the National Institute for Occupational Safety and Health awarded a research contract to the Occupational Safety and Health Research Unit of the Wisconsin Department of Industry, Labor and Human Relations for the specific purpose of analyzing human factors deficiencies in the design and operation of materials handling equipment showing high accident involvement.

Objectives of the study included the formulation of measures for prevention or correction of identified problems as well as the gathering of information potentially useful in developing improved safety standards governing equipment design and operation. An unexpected outcome was the extent to which peripheral factors, including regulatory policies, organizational features, and traditional safety practices, interact with design and use factors to produce hazards.

This introductory chapter details the rationale for the project, the scope of the area studied, and the organization of the remainder of the report.

RATIONALE FOR THE STUDY

This report is concerned with safety and health aspects of an area of activity common to industry worldwide: the movement and handling of heavy materials. Of increasing concern to manufacturing, warehousing, distribution and other industries, material handling as an organized business activity covers an astounding range of industrial fuctions and operations. The average cost of material handling is estimated to be roughly 25% of all production costs, while the actual cost may vary from less than 10% to over 90%. In rough terms, this cost includes the direct cost of equipment, including purchase price, installation, maintenance, and operating costs: manpower; indirect costs related to methods, equipment, and management effectiveness; and indeterminate and intangible costs, the latter category including safety costs. Sales of material handling equipment alone grew from a total of $600 million in 1957 to $1.3 billion in 1968 (Apple, 1972).

In viewing material handling as a problem in place utility, as compared with the form utility of the manufacturing or production process, industry has developed a highly sophisticated approach, depending increasingly on mechanization, automation, and the computer for mathematical modeling and simulation. The recognition that material handling is so interrelated with other elements of the production process, and yet has characteristics of a unified whole, has brought with it a broader view of the problem. This kind of systems approach has been said to characterize the gains in this area (Carliss, 1974), and from a technological viewpoint, this has meant greater recognition of material handling as a differentiated function important in its own right.

What has not kept pace with these gains have been results in material handling job safety and health. Attention to safety and health of the material handler has grown, but not performance and results. With the growing use of machinery, equipment, and mechanized or automated systems to lift, carry, push, pull, and otherwise move material, there has been an increase in the number and severity of occupational injuries associated with these activities.

It is undoubtedly true that over the years, the gradual incorporation of the powered industrial truck into tasks and jobs that once meant backbreaking labor for workers has eliminated many pulled muscles, backstrains, and other injuries common to manual handling tasks. The same can be said for conveyors, and to some extent, for hoists and cranes. But these equipment types are precisely those that account for the largest percentage of material handling accidents. To the extent that one accident type has been traded for another, industry has failed to integrate safety into its material handling systems. To the extent that industrial truck injuries to pedestrians have replaced back injury disabilities, the systems approaches to material handling have not encompassed a large enough system: the human factors of safety have not played an important enough role.

What has been done seems promising. Material handlers can improve existing plant layouts while jointly minimizing distance/volume, cost, and risk if the hazards are known through a computer program, COSFAD (Computerized Safety and Facilities Design) (Tomkins and White, 1977). More attention is being given to human factors and the operator-machine interface in industrial truck design than ever before. While this is due partly to the tremendous financial threat of product liability, it is nevertheless positive and should impact the safety experience of users. Yet what remains to be done seems staggering, if current accident trends continue.

The enlarged system examined in this project consisted of not only the material handling equipment and its interfaces with human operators, but the systems background within which these equipments are operated--the material handling task, the industrial environment, and the supervisory, managerial, and regulatory practices influencing their design and operation. The basic objective of identifying the human factors design and operation deficiencies became more of a starting point than a final goal. The systems nature of the safety problems studied and their dependence on interactions between humans, machines, production and management systems, and regulatory standards, have led to basic questions concerning the emphasis and structure of traditional safety practices.

SCOPE OF THE STUDY

Initial data analysis, based on Wisconsin Worker's Compensation cases and other sources (see Chapter 3--Methods), considered twelve general equipment types as candidates for study. Ranking of these based on frequency and severity results in three types: powered industrial trucks, powered cranes and hoists, and powered conveyors. Data on cases involving these types, either directly or indirectly, was analyzed and results were used in designing the field research phase.

The field research phase consisted of one or more vists to 21 industrial sites. These included three major manufacturers, one of each equipment type; seven users of cranes and hoists; seven users of industrial trucks, and seven users of powered conveyors. More than one firm was visited for two equipment types. The principal consultant reported on crane usage he studied while visiting Spain, and two researchers attended a meeting of the International Standards Organization on safety standards for powered industrial trucks in Washington, D. C. Results of observation and interviews of labor and management on the majority of these formed the backbone of the analysis and recommendations of the study.

ORGANIZATION OF THE REPORT

The chapter following the introduction details the theory and background of the study, including some of the past work of the Research Unit and the principal consultant on human factors in occupational safety and health. This is provided for a contextual understanding of later chapters. Chapter 3 presents in a general form the methods of data analysis and the field observations and interviews. Where methods were peculiar to the equipment type, these are detailed in the beginning of the chapter covering that type. These are Chapter 4--Powered Industrial Trucks, Chapter 5--Powered Cranes and Hoists, and Chapter 6--Powered Conveyors. Each of these chapters is largely autonomous and provides the most detailed levels of analysis, both of the data sources and results of the field studies. Specific recommendations are made in these chapters. Summary conclusions and general recommendations are made in Chapter 7.

CHAPTER 2. BACKGROUND AND THEORY

While cranes, hoists, industrial trucks and conveyors were the focal points of this study, the systems in which they operate are major considerations in formulating solutions to safety and health problems. Industrial work systems including materials handling systems, tasks, jobs, organizations, and social factors provide the background against which equipment design and use factors must be viewed. Supporting this view are the hazards presented in later chapters, suggesting as they do the influences of peripheral factors on accident causation. A consequence of this influence, also supported by the hazards and related factors, is that solutions to hazard control problems are anything but general. The multiplicity of sources contributing to hazards by itself suggests many options for the management of hazards, particularly in those cases where behavioral or systems deficiencies outweigh the physical features of the problem.

This chapter presents some of the definitions, concepts and techniques underlying the methods used in the study. The term "hazard," as used in this report, is given close attention, since it pervades the theory and the approach outlined here. Concepts of hazard management (Smith, 1973) which were included in the study are discussed. The relationship between hazards, hazard management in materials handling, and systems of organization (Miller and Rice, 1967) provides a link between systems analysis and causal factors. From a control point of view, these and other factors are best understood by examining accidents and hazards in relation to the regulatory efforts of all levels: self-regulation of the individual, social controls in work teams, management efforts to regulate accident occurrence, government regulatory policies and practices, and system regulation in the business and industrial environment.

HAZARDS AND ACCIDENTS

A hazard is a situation or condition which has the potential to cause an accident or injury. To understand what is a hazard or what is not a hazard, however, requires a discussion of which situations and conditions fit the definition.

In this study, hazards are perceived as dangerous situations by workers, managements, inspectors, and researchers. So perception and individual differences play a role in identifying hazards. Yet, because of their interactive nature, hidden or unseen hazards are also considered in this view, since control measures can be instituted to uncover them in the majority of cases. Conversely, the lack of control measures further complicate many hazardous conditions.

According to this view, a hazard may be the end result of a sequence of complicating and interacting factors. This partially explains the inadequacy of a single-cause concept of hazard, such as the emphasis on physical flaws and defects in the inanimate elements of the workplace. Physical defects can be devastating, as many materials handling accidents demonstrate. Failures of hooks, chains, slings, and hoist motors themselves support the need for exacting attention to engineering and strength of materials. But increasing accident rates and considerable research implicate dynamic, momentary, operational hazards as those needing more attention and study (Smith, et al, 1971; Smith, 1973; Gottlieb, 1976; Kaplan, Knutson, and Coleman, 1976).

Smith (1973) defines operational hazards as human-factors interactions between behavioral and physical, machine, and environmental factors in work. Examples of these are found in detail in Chapters 4, 5, and 6 on the specific equipment types. An overview of the types of hazards identified will illustrate their operational, dynamic nature.

The Dynamic Nature of Hazards

Momentary events such as falling crane loads, loads falling from industrial trucks, or conveyors jamming when material piles up against an obstacle, need not be hazards in and of themselves. The hazards arise when people approach the scene of these events, and the probability of injury varies as they move around. Focussing on the event emphasizes the danger rather than the cause, and prevention of injury depends on alertness, warnings, and the avoidance of impact on people. Near misses are hazards of this kind.

A less immediate hazard arises from conditions or situations favoring the occurrence of a load falling, or a conveyor jam-up. Slippery cartons are more hazardous than others in forklift operations. Oil on the floor may prompt emergency braking which in turn can dump a raised load unexpectedly. Hazards of this kind are more clearly interactive, often momentary and fleeting. But they may increase the probability that an event such as a falling load may occur. They may have a range of potentials for causing an injury, and they may worsen as combinations of different factors occur. But constant and momentary factors may combine unexpectedly, as when a crane load is being carried over workers' heads. A failure in the warning bell or horn compounds the hazard to those below.

Behavioral factors act often to compound situational or event hazards. With respect to most recognized hazards arising during materials handling tasks, behavior can further be categorized into planning and design factors, pretask preventive and anticipatory behaviors, and adaptive, protective steps or reactions when an imminent, task-specific hazard is encountered. What complicates this further is that at every stage in the development of a hazard, and in those cases culminating in an accident or injury, there are behavioral options open to the people exposed. But as the factors converge to bring about a hazard, options are reduced, especially if no preventive steps are taken.

Hypothetically, such a sequence of events might occur in planning, preparing, and carrying out a forklift task involving recognized hazards. A stack of cartons in a warehouse has tilted to a dangerous angle due to effects of humidity on the bottom cube. In planning to restack in a drier area, the plant manager and truck operator make a choice between two available trucks. The smaller truck would require more time due to its lower capacity. The larger truck could cut the time by 80%, but the forks have been known to drop several inches erractically when raised to their maximum height. Since the maintenance crew is behind in their scheduled jobs, a decision is made to use the large truck while exerting special care. The behavior of the operator from this point on is more critical to the success of the task. If preventive measures such as clearing the area of personnel and proceeding with extreme caution are not taken, only altertness and a quick jump may save the operator or unseen passer-by should the stack collapse or fall from the forks.

In the same context, negligence (conduct below some standard of care) plays a role in some hazards, but probably far less often than is implied in the common belief that 85% of all accidents are due to unsafe acts. When a hazard is the consequence of a lack of reasonable care either in ensuring someone else's safety, or in taking informed risks on one's self, negligence may be a key factor. But from a systems viewpoint, most accidents are likely to depend much more heavily on dynamic, interactive and unknown factors, with negligence assuming minor importance.

Variance: Hazards as Unprogrammed Events.

Most of the hazards discussed so far are specific to a situation; many are tied to an individual. Those presented in later chapters were either identified verbally by workers or management, or where seen by the research team and later verified. Many of these depend on the simultaneous merging of independent chains of events and are, for all practical purposes, unique situations.

Not only is every cranelift or forklift task new in some respects, and different from every other past lift, or task in minute details; even in the most repetitious mechanized processes, physical, chemical, or mechanical changes are underway. But inclusion of the human operator in the material handling task guarantees that unique event production is the rule.

Other factors contribute to the variation--both the industrial truck and the crane are called variable-path machines, and their flexibility is more of an advantage than a problem. But the more variable the task, from cycle to cycle, the more important is the human operator's role. When the task is safely completed, it is the human who has largely compensated for the countless variations, or variances, encountered on the way.

The concept of variance as used here is one introduced in the socio-technical literature of job design (Englestad, 1974) and organization design (Cherns, 1977). A variance is defined as any unprogrammed event; how serious it is depends on how critical it is to the outcome. While the concept has not been adopted by safety professionals, it is clear that hazardous events, conditions, and behaviors, even accidents and injuries, are examples of variances. The management of such unplanned events is reflected in job design, equipment design and operation, workplace layout; equipment and operation deficiencies are unplanned conditions that spawn more unexpected events. Safety and health efforts can benefit from closer attention to these so that variances are not left entirely up to the worker to manage.

Accidents and Injuries.

Disabling injuries to users of material handling equipment offer the main justification for this research. Yet the relationship between hazards and accidents, to say nothing of the part of body injured, is at best an indeterminate one. What is fairly evident from statements of hazards as workers see them is that a range of injuries could result from some hazards. Where a helper might stand on the raised forks of a lift truck to steady the load, the hazard may be the threat of the load falling on the helper, or of the helper falling to the floor. A helper threatened with a fall may grab at the mast to avoid falling and instead sever a finger in the moving lift mechanism.

These examples illustrate an often misunderstood fact about injuries and accidents. Many accidents occur as a sequence of events which ultimately end in injury or property damage. Within such a sequence, some events are deterministic or predictable while others are random. Once a powered industrial truck tips beyond a certain angle, a fall is inevitable. But the operator is still free to move during the fall, and his or her actions are only partly determined by the fall of the truck itself. The injury that might result is thus an outcome of a series of interrelated, partly dependent events, the whole of which is called an "accident." The term accident itself tends to suggest that preventive efforts are futile; new terms are introduced, such as "incident," "near miss," etc., to avoid this attitude.

The notion adopted here is that while accidents usually involve both predictable and unpredictable elements, the focus on accidents as the basis for safety efforts has detracted from the development of truly positive preventive measures. The belief that accidents are wholly "accidental" and therefore not subject to prevention or control has colored the efforts of the safety and health movement from the beginning. Worker's Compensation practices and the widespread adoption of the ANSI Z16.2 method of recording basic accident facts are examples of this, focusing as they do on the injury rather than the events leading up to it.

In a recent conference sponsored by the National Safety Council (King, 1977), participants from industry, labor and government responded with an unusual degree of unanimity to the call for the development and exchange of more useful accident, hazard and countermeasure data. This is consistent with the viewpoint stressed here that data on hazards is first of all data on work processes, workplaces and work behavior. Different kinds of data and different data standards are needed at every stage of the process from design and planning of the factory to the task itself, and from a possible injury to the compensation and rehabilitation efforts. Worker's Compensation has very definite and legitimate information needs, but these should not be confused with the requirements of the preaccident stages.

In viewing the process by which a hazard develops into an accident, several trends can be seen:

1. Factors contributing to the accident begin with remotely determined design factors, and end with specific, dynamic, physical and behavioral events. Control of these factors passes from designers, managers and supervisors, to workers.

2. Options for controlling hazards are initially wide open from the design point of view, but are progressively narrowed until the focus is on the material handling task and its associated hazards. Finally, when certain physical hazards are realized such as a falling crane load, preventive or protective actions are extremely limited.

3. At each stage of this cycle, new and different options must be considered. If the load is already in the air when a hazard develops, it is too late to redesign jobs or change the workplace layout. If the load happens to fall, it is too late for the worker to don a hardhat and steel toed shoes. At each stage, choices made help to determine what will be the options at the later stage.

The possibilities for studying safety reflect a similar trend: hazards can be recorded, analyzed, disseminated, and followed through time. If data is gathered only after accidents occur, research into the causes becomes nearly impossible. It is for this reason that the management of hazards offers the potential for positive prevention.

THE INDIVIDUAL AND THE WORK TEAM AS CONTROL SYSTEMS

Enough is known to say that the individual, or group, working with cranes, hoists, conveyors, and industrial trucks can be fruitfully studied as control systems. But the nature of this control, where the operator's control fits in with the mechanics of the machines, and where the control of the individual breaks down when it can no longer compensate for design deficiencies, must be determined through observation. We need to be able to understand how much control can be delegated to the worker by management and work process designers, how far a group of workers can go in controlling hazards through mutually communicating and warning each other, and to what extent additional surveillance and recordkeeping of such hazards can supplement the self-regulation and self-protection process.

Personal Hazard Control by the Individual

A major portion of this project, the informal interviewing of workers regarding hazards in the design and use of cranes, conveyors, and industrial trucks, was based on the theory of hazard management (Smith, 1973: Coleman and Smith, 1976), and its emphasis on the worker's role in identifying, eliminating and regulating hazards and the behaviors defining them. There are many reasons for relying on worker input in hazard control, not the least of which is the increased responsibility and potential for self-determination that can result. And there is little doubt, among the management people interviewed in past projects, that the worker is the best single source of information on specific job hazards.

Yet the most critical aspect of worker control of hazards is that it needs to be recognized in a formal way by management. If worker performance in hazard identification and control is not managed, three results are likely to be obtained. First, skilled, knowledgeable, and experienced workers will have ways of adapting to hazards that may not be shared with new hires, and unskilled labor. Second, workers may develop elaborate, time-consuming defenses against perceived hazards which in many cases can be eliminated or abated inexpensively by safety management. Third, assessment of causal factors in investigating accidents will be extremely difficult if not impossible.

The commonly understood "unsafe act" demonstrates one kind of result of this last type, when it is labeled as a causal factor in an injury. Worker comments in the hazard surveys conducted by the Research Unit show that when a hazard is recognized, what may appear to be unsafe to an observer may in fact represent carefully thought out actions in which alertness and caution reduce the risk greatly. The factor that is omitted when such an act is blamed for an accident is the "exposure:" how many times has this same unsafe act been performed without incident, and why were the precautions finally inadequate? A thorough analysis of the accident cannot ignore the self-management efforts of the employe in performing safely prior to the injury. Unseen hazards or possible variances should be looked for in helping to explain what went wrong.

The first step, therefore, in managing safe performance is finding out and recording what people <u>do</u> to prevent hazards from causing accidents. For example, experienced lift crew workers will relate the hazards of trying to stop a multi-ton load from spinning as it's hoisted from the floor. Where the inexperienced hitcher will inadvertently put a hand out to try to stop a heavy, turning load, the knowledgeable crew member will let the load stop by itself or fall from the hook before risking a hand or an arm.

What "controls" does the individual have available in regulating safe behavior on the job? In the material handling tasks studied here, not surprisingly, the worker has available many of the options management has in designing, operating and maintaining a productive system. The worker can, first, plan his or her activities. To an extent, this means design of the task. And except for certain routine jobs related to conveyor applications, on jobs involving powered industrial trucks, cranes, and hoists, this kind of planning is a requirement of the task. The operator responsibile for operating a variable-path device of necessity must plan the move to avoid obstacles. In practice, this avoidance reduces to the navigational skills of traversing tight aisles, turning tight corners and avoiding tipping hazards, but planning skills show in the knowledge of plant layout and alternate paths to the same end.

As the task of moving is carried out, the systems nature of the operator defines the limits of personal control. As self-regulated, feedback controlled organisms workers control their movements within specific, spatial and temporal limitations. The physiological mechanisms of vision, hearing, and the tactual/kinesthetic senses depend on continuous, immediate feedback of the effects of body movements. Factors impairing these mechanisms such as drugs, alcohol, fatigue, stress, and physical disabilities related to past or present illnesses, obviously have direct impact on personal control. Conversely, people in good health and physical condition adapt readily to a wide range of demands which arise as they work. Beyond the control of body movements, alert workers use vision, hearing, and speech to widen the boundaries within which they can impact events. A hitcher can yell at the cab operator to change the course of a swinging load, while a pedestrian can step out of the path of a truck whose operator can't hear the verbal warning, if these options are available. In short, the alert human operator controls fairly effectively a sphere centered about the body and limited by his or her ability to affect events at a distance through personal actions.

What cannot be controlled and what the physical and physiological limits of control are, cannot be determined without human factors principles and experimental observations. In particular, operating sit-down and other rider industrial trucks, overhead cab-controlled and mobile cranes is subject to the constraints defined by the exoskeletal properties of these machines (Smith, 1966). Formulated by this project's senior human factors consultant during his work with the General Electric Company in developing anthropomorphous lifting and walking machines, the main features of the theory account for the fact that mobile machines in general consist of an external metal exoskeleton within which the operator moves in manipulating machine controls. Since gravity affects both the vehicle and the operator, attention must be paid to the relationships between the operator and the machine, the operator and the roadway or fixed support elements, and the machine and the roadway or supports. The aspects of this theory important to materials handling safety are these:

1. The exoskeleton of the truck or crane cab, including the controls, steering wheel, brakes, and lift mechanisms, provide a variety of mechanical, visual and auditory feedbacks to the operator. Judgments about the condition of the road or support surface, or about load characteristics such as weight and stability, are based on this feedback from the machine and its movements. Where vision or hearing indicates one state of affairs, feedback from the exoskeleton may indicate another.

2. The compliance of the movements of the truck or crane cab with those of the operator determines the smoothness and ease of control. That is, if the cab or its moving parts, including hand and foot controls, either display or require movements with rates, accelerations, or spatial characteristics different from those of normal postural, limb travel, and manipulative movements of the operator, the control of the machine may be compromised.

Many factors in the ergonomics of controls design, including foot-pound requirements for maximum application of force to the truck brake pedal, have gone into modern design of materials handling equipment. Yet where the compliance needs of the operator become critical is not easily found by controlled or laboratory methods, since emergency or stressed situations can compound the problems and cannot be easily simulated. Nor can experience or training offset or negate such problems, especially those that might involve delay of feedback to the operator. Smith (1973) demonstrated the decrease in learning that takes place in visual-manual tracking as visual feedback delay is increased from zero to several seconds, although delays were not among the problems cited by truck or crane operators (see Chapters 4 and 5).

Social Controls in Work Teams

As with the individual or the industrial enterprise, the working team exhibits some of the characteristics of open systems. The lifting crew of three hitchers, a supervisor, and a cab crane operator thirty feet above the floor, the industrial truck operator with a pedestrian helper restacking pallets, or the team of two people banding boxes with steel strap on a conveyor line, may be thought of as task systems. With input-conversion-output processes, self-regulatory management, and boundaries both spatial and psychological, these groups tend to have fewer accidents per hour of exposure than employes working alone (Preiwisch, 1977). In most work situations, a group may have a designated supervisor, team leader or lead worker, but often only informal authority relationships are seen. Problems arising from these variable and nonstandard relationships show up in the management of lifting operations with overhead cab controlled cranes. Most industry people agree that the overhead cab operator has final responsibility for the integrity of the load hook up. Yet worker comments reveal a wide range of practices. In one plant, the cab operator exercized veto power over a lift by simply refusing to engage the controls until the hitchers guessed what his objections were and corrected the situation.

As task or activity systems (Miller and Rice, 1967), material handling crews have a primary task to complete, whether it is movement of unit loads from receiving to storage or simply the turning of a 30-ton cast steel machine housing. Planning is frequently a main part of the task. In a large paper machine factory, heavy and awkwardly shaped objects were lifted by crane only after photographs of the part were taken, examination of these for determination of probable center of gravity was done, and the object marked or cut for the appropriate sling and hook attachments.

Groups of workers engaged in a common task therefore exhibit control characteristics similar to those of the individual. Amplifying these are the social tracking and communication that commonly must take place for the group to carry out a joint effort (Smith, 1973). People working in such a group expect one another to know what the others are doing. Warnings of falling loads or other impending hazards can avoid injuries which might otherwise be unavoidable for a lone worker. The lone worker, in fact, is often a casualty in industrial truck and crane operations apparently because he does not enjoy the closer communication characteristic of the team action.

Injuries to pedestrians who appear suddenly in a truck's path, and injuries to preoccupied workers such as welders in the vicinity of a swinging crane load, are mentioned by industrial personnel and verified by the statistics.

MANAGEMENT'S TASKS IN MATERIAL HANDLING SAFETY

As the main planners of corporate and organizational goals, management makes decisions that ultimately influence plant safety as no one else does. As builders and assemblers of tools, consisting of both machines and people, to achieve these production goals, management predetermines through design and planning whether plant safety will be a "natural" feature of everyday operations, or a function which will largely compensate for poor human factors design of the workplace, the tasks, the jobs, and the equipment and tools used to carry them out.

These problems are particularly true for material handling. Even in a warehouse where 90% of the handling is done by self-propelled walkie trucks, selection of the appropriate make, model, and number of trucks needed cannot be done by consulting catalogs only. Depending as it does on material characteristics, movement requirements and equipment capabilities (Apple, 1975), selection of trucks, especially with safety in mind, depends on, and impacts, workplace layout, job design, and material flow, storage requirements, and countless other factors. Similarly, selection plays a major role in conveyor usage and the adaptation of a complex conveying system to a large plant. Jointly optimizing this arrangement with safety needs and human factors, including the need to walk over or under the conveyor or to lift objects to and from it, means simultaneously designing the conveyor and the work processes which interact with it.

From a broader persepective, management has long-term control over these areas:

1. Planning the workplace, including the selection and placement of fixed elements of workplace layout.

2. Selecting the tools, equipment, machines, and other movable items.

3. Planning the work to be done, including tasks and their allocation to people, machines, and jobs.

4. Selecting and preparing the worker through personnel selection, training, and setting experience and supervision requirements for certain jobs.

5. Managing the work and the hazards though effective identification and reporting of operational data, primarily by evaluating performance in relation to previously set standards, objectives, and goals.

The order of these tasks is relevant only in a logical way. In practice, all five may proceed simultaneiously.

Planning and Design of Workplace Layout

Traditionally, the responsibility for "unsafe conditions" has rested with management. Workplace layout--the configuration of machines, aisles, walls, pillars, stairways, ramps, doors, storage racks, and the work processes that determine how people move around in the layout--is one of the main sources of constraints that lead to hazards. Roughly 20% of the hazards mentioned involved elements of workplace layout (see Chapters 4, 5, and 6).

Fixed physical characteristics of the workplace--aisle widths, vehicle routes, machine placement, door size--are rarely in themselves "unsafe conditions," although OSHA and ANSI standards specify some of these in great detail. They are better viewed as constraints, within which more movable items, including workers, must continually adjust and regulate their positions. They become contributors to hazards only in relation to the more mobile, adaptable elements. Narrow aisles are cited often by industrial truck operators as contributing to a dangerous situation. Yet it's the width in relation to truck size, or turning radius, or load size and shape, that defines the hazard.

To the extent that management controls it, workplace layout defines an important factor in material handling safety. But since the fixed elements of the layout combine with the movement of other elements to create hazards, prescriptions for safe layout alone are difficult. What is needed is an open-minded management attitude and the communication necessary to ensure that layout and layout related hazards are considered whenever changes in equipment, structure, process, or personnel are anticipated.

Selection and Design of Equipment and Mobile Items

The selection of equipment for materials handling is a key activity from a cost and efficiency viewpoint. Usually approached from a problem point of view (Apple, 1972), selection of appropriate components for a system can be extremely complex; yet wrong decisions can result in a plant full of new machines which is essentially obsolete (Rowan, 1977). And the impacts of poor selection on safety may result in hazards turning up for years afterward.

In systems terms, selection is an aspect of design. Users of cranes, hoists, trucks and conveyors can select only those that are designed and marketed by manufacturers. But manufacturers are influenced by what sells, by user needs, by government regulation, and by competition. Over a period of time, user selection influences design greatly.

From a workplace viewpoint, the user does more design than selection by assembling a unique set of components for particular purposes. Equipment design interacts so closely with workplace layout, storage methods, movement requirements and so on, that the design of the final operating system is truly in the user's hands. And the hazards that arise can more often be characterized as deficiencies in the total design than as defects in particular trucks, cranes or conveyors.

Hazards can arise from mismatches between equipment and layout factors, between operator and equipment, between equipment and load characteristics, and between combinations of these and others. An example that came up frequently on our site visits involved the choice between cab or pendant control of overhead cranes. Workers having experience with both types tended to prefer cab control (see Chapter 5), partly because pendant usage requires working close to the suspended load. Cab control allows the worker to stand clear after the hitching is done. But the safer choice was by no means clear, and different managements gave different reasons for theirs. Work activity in the crane bay was a main criteria: others were distance of transports, availability of a path for pendant controllers, and frequency of usage of the crane itself.

The flexibility of an either/or situation delegates to the worker a part of the selection task. Cherns (1977) established this as a principle of socio-technical design, namely, that at each stage of design, only the minimum critical specifications should be made. Practically, this includes consulting the worker about potential problems and hazards as a part of equipment selection as well as providing flexibility of options for safe performance.

Examples of the interplay between industrial truck design and storage practice, job design and other factors are detailed in Chapter 4. One worker cited an oblong pallet rack that was stored lengthwise. But the truck had forks so short that only widthwise engaging of this particular load was safe; picking up the load on its narrow end meant the risk of tipping the truck.

Planning the Work to be Done.

From a material handling standpoint, a recent trend has been the increasing use of machines to both mechanize and automate the process of moving materials. Precisely where humans are needed or used in the process depends on many factors including the product manufactured, the technology available to produce it, and the characteristics of the labor force available to operate it. A high priority for safety and health in this process of allocating work to machines versus people is needed and the area is another where management has responsibility and control.

The two areas requiring specific attention are operations design and job design, as these both affect and are influenced by material handling decisions and practices. By operations design we refer simply to the overall pattern of work or product flow through the workplace. Features of operations on materials such as the number of distinct operations required to complete the product, the organization of these operations by function or process, time characteristics of different product flows, and storage and movement requirements of raw materials, help to dictate the choices and decisions of the material handler. Traditionally the province of plant engineers, design of the operations necessary for production needs input from safety and health personnel and from those workers skilled in identifying hazards arising in various operations.

Job design, according to the same view, is inseparable from the work to be done. Neither job nor operations design can be carried out without the one depending on the other, especially in cases like warehousing where movement is both job and product flow at the same time.

In material handling, and particularly in the use of conveyors, industrial trucks and cranes, job design is more often a result of selection and layout factors than an equal consideration. Job design features of interest here are those that relate to product flow, such as numbers of workers performing identical tasks, relationship of one worker's job to the finished task or product, and other division-of-labor questions. Wage systems are considered a part of job design also, especially since piece rates, bonuses, and other incentive pay systems directly affect worker attitudes and actions in dealing with hazards.

Problems anticipated and later verified in the project included questions of what role material handling played in a particular job. This varied along the entire scale from conveyor related jobs requiring constant monitoring of product quality to skilled machinist jobs where workers used a small jib crane once or twice per day to turn a piece of lathe work. Operators of powered industrial trucks and overhead cranes were more likely to be involved in full time material handling, but there were many exceptions to this. Some crane operators ran one of two or three overhead cranes, alternately climbing from one to the other as required by operations. In warehouses, operators of order picking trucks piled and repiled cartons and cases on pallets as they alternated between storage and retrieval tasks.

Pay systems were expected to show an influence on hazards. As an apparent consequence of industrial engineering practices, industrial truck drivers, and crane operators to some extent, in showing understandable variations in the time required from task to task, are not subject to the same time and motion standards applied to others. Consequently, time pressures exerted by paced job production workers on industrial truck operators were mentioned by workers as compounding other hazards.

As one large user of conveyors told us, conveyors don't usually require an operator; they most often serve to carry products from one machine or operation to the next. But people are inserted into the largely automated process at only those points where variations in product line, carton type, or raw material require human judgment and flexibility. People in this operation interface with the conveyor and related machinery by monitoring and ensuring that the proper supplies and materials are available as inputs to the process. Doing this by machine was perhaps possible, but not efficient or economically feasible. Yet the input requirements were not the only variances compensated for by the worker; the main hazard associated with one such job was the frequent jamups that occurred which called for manually removing jammed cartons and risking a caught-in injury to the arm or hand.

Worker Selection and Training

Industrial organizations are systems open to the hiring and discharging of individual employes, and one of management's tasks, increasingly influenced by government regulatory policies, is to effectively select and prepare workers for their tenure with the establishment in an effort to minimize the detrimental impacts of work and working on these people's lives, safety and health. The material handling jobs handled by industrial trucks, conveyors, and cranes offer good examples of the need for careful selection and training.

The relevance of human factors design of trucks, cranes, hoists and conveyors to training is based on the fact that design precedes training. The latter is useful only if it is specific to the equipment to be used. But related to this is the fact that training cannot offset poor human factors design of machines and equipment (Goldstein, 1975). The variation in human performance resulting from varying tool, machine and operations design is much greater than that produced when training is varied (Smith, 1975). In a systems theory of safety, training and selection attain importance in relation to design as supplementary activities, rather than substitutes for thinking through human factors at the planning stage.

The concepts of industrial truck and crane operator selection and training are not new to material handlers. Literature and films on operator training are readily available from major manufacturers, and from related associations. An outline of medical, physiological, and performance considerations used by a major producer of industrial trucks (Industrial Engineering Magazine, September 1975) is supported by a number of hazards found in this research and detailed in later chapters. For example, the overriding importance of good vision in operating industrial trucks, especially in plant environments where high noise levels mask warning sounds, can be inferred from the outline. Stressed also are the importance of good hearing and freedom from the problems associated with cardiac diseases, diabetes, excessive weight, and others.

Operator training is also incorporated into the package available from the chief producers of material handling equipment. And the data seem to reflect this availability and the use of manufacturer's training programs: a large percentage of industrial truck operators interviewed reported that training of some kind had been given them. Prompting some of this is Section 1910.178 of the Occupational Safety and Health Standards which mandates that only trained and authorized persons be allowed to operate powered industrial trucks, but common sense and a need for damage control have always been good reasons for such training also.

Yet from the hazard management viewpoint, improvements need to be made in all the areas of selection, training, authorizing and managing of people exposed to the hazards of these operations. This theory assumes that increased surveillance, recording and tracking of specific operational hazards has implications for each of the functions mentioned. Selection needs to be made, but tailored to the requirements of the plant and existing conditions, not necessarily only to those of the manufacturer or dealer. The hazards of operating an overhead crane in a foundry so dark that flashlight signals from hitcher to cab operator are necessary, demand more than just a person with good vision. Ideally, experience requirements are needed which go beyond selection criteria.

Experience, in fact, is the quality believed to distinguish the safe materials handler from the rest. That training of the traditional kind can only provide limited experience is evidenced by the highly complex, varied and interactive nature of the hazards cited by industrial people. Since hazards often represent the combination of a number of unanticipated conditions, behaviors and other variances left unmanaged or uncommunicated, they are not incorporated into the standard training programs. Those programs that require supervised on-the-job practice may allow the operator exposure to hazardous situations; but a program requiring periodic hazard review in safety meetings can supplement training precisely where it is the weakest. In some ways, only experience and the exposure to a wide range of varying conditions and situations can adequately prepare an operator for certain jobs.

Preventive and Emergency Maintenance

That machines, equipment and tools do wear out is a fact of life faced by material handlers in all areas. Over its economic life of 5 to 6 years, a powered industrial truck will accumulate maintenance costs that are 90% or more of the original acquisition cost. A cost conscious management will save considerably by replacing a truck at this point, since maintenance costs will rise rapidly if the truck is kept in use.

Results of earlier hazard surveys illustrate, however, that maintenance does not receive the attention it deserves from the safety viewpoint. Roughly 15% of cited hazards involved physical conditions felt by workers or researchers to be the responsibility of maintenance personnel (Coleman and Smith, 1976). In the current research, maintenance problems directly affect physical conditions of all workplace elements. In many cases, these can be compensated for by extra caution and a clear understanding of the malfunctioning truck, crane, hoist or conveyor. Workers cited many hazards resulting from poor lubrication of truck parts, patchwork solutions to problems with poorly designed machines, or low priorities on small repair problems due to heavy maintenance needs elsewhere. In one establishment, the majority of walking forklifts had their handles taped up to prevent them from falling to the floor. Springs designed to return the handle to the upright position were in disrepair.

Problems with maintenance are not always solved by that function alone. Workers admitted to keeping a poorly running truck in use beyond the safe point, sometimes as a result of speed pressures or heavy work schedules, or from the knowledge that maintenance would tie the truck up for several days. Workers instructed to retire a problem truck to the maintenance shop often keep it running until the end of the shift, rather than travel the distance required or fall behind in their work.

The theme of interaction central to this theory applies to the management of maintenance as it affects safety and health in material handling as elsewhere. The boundaries of a maintenance subsystem need special regulation by management, especially in industries where maintenance workers are the most skilled and highly paid labor in the plant. Problems of social interaction are reflected not in the quality of maintenance work, but in the hazards left to production workers when the maintenance crew leaves jobs half done and machine parts piled in the wrong places. Management's task is not only to ensure that physical breakdowns are anticipated through scheduled preventive maintenance or repaired when emergency malfunctions occur. This aspect is crucial, since physical and mechanical changes can introduce unknown variances in the most carefully controlled processes. But the task must be enlarged to cover relationships between maintenance and production, or maintenance and material handling. The functions are different, and will have different objectives, goals, and different incentives to achieve them. The time urgency is one of several key differences, and one outcome contributing to hazards is that untrained operators attempt maintenance on their own machines rather than wait for the mechanic to do the job. But these are all the more reasons why effective management is needed to settle disputes and thereby better manage the hazards.

The Separation of Safety and Production Managements

Most industrial organizations employing more than a dozen or so people have a differentiated management function. For smaller groups, especially cooperatives, an informally designated leader who works on the same tasks as do the other employes may constitute management. These groups and small businesses may effectively contribute to the economy while largely self-regulating their affairs as individuals and as a group. But where size or complexity or other factors have brought about a need for control above that afforded by self-regulation, people begin to do tasks loosely grouped under the term management (Miller, 1959).

Most organizations with materials handling needs also have differentiated functions of maintenance, although some industrial truck dealers provide maintenance services for small buyers. Some have separate personnel departments, purchasing functions, accounting, marketing, and other usual business functions. The largest have a separate material handling division, and almost all have some safety and health function. Very few have a research function, except perhaps as a marketing or product development adjunct.

By analogy with biological organisms, these differentiated activities are natural, as most systems with some open characteristics have them in common. A generalized form of maintenance must take place to furnish the system with raw materials, energy, and supplies, and to dispose of waste and other depleted resources. The main operating activity, corresponding in industry to the pursuit of the main business purpose or mission, must be carried out. And management must regulate these import-conversion-export processes, the various functional activities, and the relationships between them. Miller and Rice (1967) present these concepts with refinements in Systems of Organization.

What role does occupational safety and health play in a systems structure such as this? The theory of hazard management offers no generalized systems function analogous to safety and health except management itself. The view put forth here is that safety and health are the result of effective regulation and control of hazards on all levels. One logical place for plant safety is therefore as a part of management, but not necessarily division or department management. Since control of hazards involve almost all major functions, safety and health should be lodged at a level high enough to command the integration of these functions.

Studies have shown that plants with low accident rates tend to differ in a significant management way from similar plants with high accident rates (Cleveland, 1977). This is the top management commitment to safety and health evidenced by the high level of the ranking safety official in the hierarchy. Supporting this in an indirect way are the hazards detailed in later chapters of this report. One other reason why these hazards call for high level action is the systems nature of material handling itself--powered industrial trucks, cranes and hoists and conveyors jointly cut across departmental and functional boundaries in moving material in, through production, and out of the plant. Only in an organization where safety management has the authority to regulate accident occurrence across all these boundaries will joint safety and health measures be taken.

It is this reasoning that has led to the theory that management of hazards differs in no real way from the management of production, of material handling, of maintenance, or of industry in general. The tasks of management relevant to controlling hazards are those of management anywhere: the setting of objectives and goals, including standards of performance; the careful evaluation of progress relative to these standards; and the responsible regulation of the work process to make the work productive, the workers achieving, and to keep the adverse impacts on them to a minimum (Drucker, 1974).

The concept of performance standards for safety demonstrates how worker, supervisor, and management objectives can be set in areas relevant to hazard control (Smith, 1973). Especially appropriate for powered industrial trucks is the need for standards of housekeeping, training, preventive maintenance, and hazard review. Standards of experience in selecting truck and crane operators for hazardous tasks need to be established, but on a plant by plant basis. Human factors design, attention to job stress factors, and preventive maintenance are areas where conveyor operations need performance safety standards.

GOVERNMENT STANDARDS AND WORKER SELF-REGULATION

Materials handling equipment users must comply with a series of OSHA regulations, many of which are based on ANSI standards, and these are some of the most specific and detailed standards currently in effect. As with many types of standards, however, they demonstrate the inherent difficulty in regulating personal behavior through legal and administrative policy statements.

As mentioned earlier, a general assumption guiding this project was that most of the observable crane, conveyor, and industrial truck related problems are variable operational hazards depending on conditions and use of the equipment which are influenced by management supervision and which are not necessarily related simply to the physical characteristics of the equipment and the surrounding workplace. Whether such hazards can be effectively detected or observed through inspection without extensive intervention into the task itself, including communication with workers and supervisors as to their alertness and any precautions they might be taking, is an operational problem relevant to the entire area of management. The records, data and information needed by management varies extremely depending on the operation, but systems management, management-by-objectives, and other well-known theories have been formulated to answer these needs.

Promulgating and enforcing safety and health standards is analogous to writing job descriptions as a list of objectives and then trying to manage the work with these statments alone. It has been noted (Cornell, et al, 1976) that OSHA, under Congressional mandate and pressure for early results, adopted by inclusion and reference a set of standards written by the American National Standards Institute for purposes other than Federal enforcement. As partial job descriptions for OSHA compliance officers and for industry personnel responsible for compliance with them, these standards determine the focus and the priorities of the safety efforts in industry. It is the assumption that they can substitute for effective hazard management that is being questioned here.

Standards Governing Material Handling Equipment

Those OSHA regulations that require specific training, skills and behavior from equipment operators, and specific designation, authorization, and preparation of these operators by management, are found in 29 CFR 1910.178 (Powered Industrial Trucks), and in 29 CFR 1910.179 and 1910.180 (Cranes, Overhead and Gantry, and Crawlers, Locomotive and Truck, respectively). These regulations also specify that inspection and maintenance, and record-keeping of these activities, be carried out.

A review of these regulations shows that OSHA has promulgated a number of operational and performance requirements on the part of management of users of cranes, hoists, and industrial trucks that are not subject to inspection of equipment. They depend on positive cooperation of plant management and considerable breadth of interpretation by both management and OSHA compliance officers in defining compliance with them. For cranes, these include:

Designation of Personnel: Only designated personnel shall be permitted to operate a crane covered by this section (1910.179(b)(8)).
Operator Knowledge: The employer shall ensure that operators are familiar with the operation and care of fire extinguishers provided (1910.179(O)(3)).
Frequent and Periodic Inspections: Frequent inspections (daily to monthly intervals) of all functional operating mechanisms, deterioration or leakage in lines, tanks, valves, drain pumps, etc., hooks with deformation or cracks, hoist chains, etc. (1910.179(j)(2)(i) through (j)(2)(vii); periodic inspections (1 to 12 month intervals) of deformed cracked or corroded members, loose bolts or rivets, cracked or worn sheaves and drums, etc.(1910.179(j)(3)(i) through (j)(3)(x)).
Testing: Tests of initial capacity and operations for new or altered cranes are required and procedures specified (1910.179(k)).
Maintenance: Preventive maintenance procedures are mandated by the standard, as are safety procedures to be followed during maintenance operations. Maintenance repairs are required to correct hazards uncovered in the inspection process before the cranes are allowed back in use (1910.179(1)).
Rope Inspection: Requirements for monthly testing procedures to check and determine the integrity of both metal or other ropes used on crane hoisting mechanisms. Specific conditions such as corrosion, kinking, and wear require attention, as do rope end connections. Ropes used only infrequently must also be inspected and passed prior to their usage. All of these reports must be signed and filed (1910.179(m)).

Operator Performance Requirements: These standards include procedures for handling and moving loads with overhead cranes; hazardous operations are mentioned and requirements of personnel or employer responsibility are established for these situations.

For powered industrial trucks, these standards include:

Operator Training: Only trained and authorized operators shall be permitted to operate a powered industrial truck. Methods shall be devised to train operators in the safe operation of powered industrial trucks (1910.178(l)).
Truck Operations: These subsections require that trucks not be driven up to persons standing in front of benches or other fixed objects, that no unauthorized passengers are carried, that safe distances from edges of platforms are maintained, etc.(1910.178(m)).
Traveling: This includes requirements that plant speed limits be observed, that the operator slow down and sound horn at an intersection, that speed be reduced to negotiate turns, etc. (1910.178(n)).
Loading: Only stable or safely arranged loads may be handled, load engaging means shall be placed under the load as far as possible, etc. (1910.178(0)).
Operation of the Truck: These require that trucks in need of repair be taken out of service, no truck shall be operated with a leak in the fuel system, etc. (1910.178(p)).
Maintenance of Industrial Trucks: These standards require that all repairs be made by authorized personnel, that trucks used round-the-clock are examined after each shift, etc. (1910.178(q)).

These are not presented as comprehensive or direct quotes of the relevant regulations, but to serve as examples of performance based standards, rather than specification standards which are often capable of verification through physical, static measurements.

Standards such as those referred to above attempt to define safe performance on the part of the crane or truck operator. The assumption of this research is that such performance standards can be meaningful and effective extensions of the more basic physical standards. Performance standards currently govern production, time characteristics of work, product quality, and other aspects of modern work processes. But considerably more effort is required to incorporate such standards into today's safety practices than that demanded by compliance with the primarily physical standards of OSHA.

The management of workplace hazards as outlined in this section assumes that the lack of performance based safety standards underlies the increasing problems of occupational safety and health today. Since behavioral performance codes imply specific solutions to the countless varieties of hazards faced by today's worker, Federal "standardization" of such rules may be impractical. But Federal efforts to define the key activities of safety and general standards for their performance are needed; this means auditing safety programs in addition to checking compliance with physically measurable standards. What is needed more are voluntary efforts by industry to develop the hazard detection and hazard control instruments which are both tailored to the particular workplace and yet comprehensive enough to reduce injury and illness rates.

REFERENCES

Apple, J.M. Lesson Guide Outline on Material Handling Education. Pittsburgh: The Material Handling Institute, Inc., 1975.

Apple, J.M. Material Handling Systems Design. New York: The Ronald Press Company, 1972.

Carliss, O.S. Human Factors Considerations in Materials Handling Systems Design in Proceedings of the 1974 MHI Inter-Society Material Handling Symposium. May 21-23, 1974. Pittsburgh: The Material Handling Institute, Inc.

Cherns, A.B. Can Behavioral Science Help Design Organizations? Organizational Dynamics. New York: AMACON, 1977.

Coleman, P.J. and Smith, K.U. Hazard Management. Madison, Wisconsin: Wisconsin Department of Industry, Labor and Human Relations, 1975.

Cornell, N.W., Noll, R.C., and Weingast, B. Safety Regulation. In Pechman, J.A., Ed., Setting National Priorities: The 1978 Budget. Washington, D.C.: The Brookings Institution, 1977.

Cleveland, R.J., Cohen, H.H., Smith, M.J., and Cohen, A. Safety Program Practices in Record-Holding Plants. Cincinnati, Ohio: National Institute for Occupational Safety & Health (Report submitted for publication).

Drucker, P.F. Management: Tasks, Responsibilities, Practices. New York: Harper and Row, Publishers, 1974.

Engelstad, P.H. Socio-Technical Approach to Problems of Process Control. In Davis, L.E. and Taylor, J.C. (Eds.), Design of Jobs. Middlesex, England: Penguin Books, Ltd., 1972.

Goldstein, I.L. Training. In Margolis, B.L. and Kroes, W.M., The Human Side of Accident Prevention. Springfield, Illinois: Charles C. Thomas, Publisher, 1975.

Gottlieb, M.S. Worker's Awareness of Industrial Hazards: An Analysis of Hazard Survey Results from the Paper Mill Industry. Research Report released by Wisconsin Department of Industry, Labor and Human Relations, Research and Statistics Bureau, Madison, Wisconsin, 1976.

Industrial Trucks - Their Operation and Maintenance. Industrial Engineering, September 1975, Vol. 7, No. 9, pp. 32-37.

Johnson, W.G. MORT: The Management Oversight and Risk Tree. Journal of Safety Research, March 1975, Vol. 7, No. 1, pp. 4-15.

Kaplan, M., Knutson, S., and Coleman, P.J. A New Approach to Hazard Management in a Highway Department. Research Report released by Wisconsin Department of Industry, Labor and Human Relations, Research and Statistics Bureau, Madison, Wisconsin, 1976.

King, K. Occupational Injury Information & Systems: Problems, Options for Improvement, and Areas for Action. Report prepared by Safety Sciences, Inc. for the National Safety Council, Chicago, Illinois, 1977. Stock No. 129.31.

Miller, E.J. Technology, Territory and Time: the Internal Differentiation of Complex Production Systems. Human Relations, 1959, Vol. 12, pp. 243-272.

Miller, E.J. and Rice, A.K. Systems of Organization. London: Tavistock Publications, Limited, 1967.

Preiwisch, A. Do Lone Workers get More Injuries? Industrial Supervisor. April 1977, Vol. XLI, No. 4, p. 7.

Rowan, M.J. New Machines Alone Won't Stop Obsolescence. Modern Materials Handling, October 1977, Vol. 32, No. 10, p. 47.

Smith, K.U. Review of the Principles of Human Factors in the Design of the Exoskeleton and Four-legged Pedipulators. University of Wisconsin Behavioral Cybernetics Laboratory, Madison, Wisconsin, 1966.

Smith, K.U. and Smith, M.F. Psychology - An Introduction to Behavior Science. Boston: Little, Brown and Company, Inc., 1973.

Smith, M.J., et al. Inspection Effectiveness Report. Madison: Wisconsin Department of Industry, Labor and Human Relations, 1971.

Tompkins, J.A. and White, J.A. Location Analysis - More Than Just Plant Layout. Modern Materials Handling, September, 1977, Vol. 32, No. 9, pp. 64-70.

BIBLIOGRAPHY

Ackoff, R.L. and Emery, F.E. On Purposeful Systems. Chicago: Aldine-Atherton, Inc., 1972.

Ashby, W.R. An Introduction to Cybernetics. New York: John Wiley and Sons, Inc., 1966.

Ashby, W.R. Analysis of the System to be Modeled. In Stogdill, R.M. (Ed.), The Process of Model-Building in the Behavioral Sciences. Ohio: Ohio State University Press, 1970.

Cherns, A.B. and Clark, P.A. Task and Organization: Military and Civilian. In Miller, E.J. (Ed.), Task and Organization. New York: John Wiley and Sons, Inc., 1976.

Davis, L.E. The Coming Crisis for Production Management: Technology and Organization. In Davis, L.E. and Taylor, J.C., Design of Jobs. Penquin Books, Ltd., Harmondsworth, Middlesex, England, 1972.

Edholm, O.G. The Biology of Work. New York: McGraw-Hill, 1967.

Grether, C.B. Engineering Psychology. In Margolic, B.L. and Kroes, W.H., The Human Side of Accident Prevention. Springfield, Illinois: Charles C. Thomas, Publisher, 1975.

Hardie, C. Materials Handling in the Machine Shop. Brighton, Sussex, U.K.: The Machinery Publishing Co., Ltd., 1970.

Howell, W.C. and Goldstein, I.L. Engineering Psychology. New York: Appleton-Century-Crofts, 1971.

Lind, R.L. and Weber, J.E. Radio Control for Cranes. Conference Paper - Joint IEE/ASME Material Handling Conference, Milwaukee, Wisconsin, October 27, 1971. New York: The Institute of Electrical and Electronics Engineers, Inc., 1971.

Matthyson, H.J. The Cost of an Accident and How It Affects Profits. In Widner, J.T., Selected Readings in Safety. Macon, Georgia: Academy Press, 1973, pp. 209-215.

McCormick, E.J. Human Factors in Engineering and Design. New York: McGraw-Hill, 1976.

Meister, D. and Rabideau, G.F. Human Factors Evaluation in System Development. New York: John Wiley and Sons, Inc., 1965.

Miller, R.B. Task Description and Analysis. In Gagne, R.M. (Ed.), Psychological Principles in System Development. New York: Holt, Rinehart, and Winston, 1962.

Perrow, C. Organizational Analysis: A Sociological View. London: Tavistock Publications Ltd., 1970.

Rice, A.K. Individual, Group and Intergroup Processes. In Miller, E.J. (Ed.), Task and Organization. New York: John Wiley and Sons, 1976.

Rickson, R.E. Knowledge management in Industrial Society and Environmental Quality. In Human Organization, 1976, Vol. 35, No. 3, pp. 239-251.

Rogers, J.G. and Armstrong, R. Use of Human Engineering Standards in Design. In Human Factors, 1977, Vol. 19(1), pp. 15-23.

Rogers, J.G. and Pegden, C.D. Formatting and Organization of a Human Engineering Standard. Human Factors, 1977, Vol. 19(1), pp. 55-61.

Smith, K.U. Behavioral Practices in Risk Management of Industrial Safety and Workers' Compensation. Wisconsin Department of Industry, Labor and Human Relations, Research and Statistics Bureau. Madison, Wisconsin, 1975.

Smith, K.U. General Theory of Human Motions. Proceedings of the 14th International Congress of Psychology, 1954, Vol. 38, pp. 126-130.

CHAPTER 3. METHODS

This chapter presents the methods used in gathering data to define the scope of the study and in researching through field visits and observations the human factors and causal factors questions indicated by the data. Included are brief discussions of the accident data sources used, and of the techniques used during the site visit observations. Comments are also included on the final appraisal, analysis and presentation of the research results. Each of the relevant chapters (Chapters 4, 5 and 6) details those methods peculiar to that equipment type alone.

STUDY METHODOLOGY OVERVIEW

There were essentially three phases of study in this project:

1. Initial gathering and analysis of data to determine the scope of the study and to indicate the directions to be pursued during later phases. This included narrowing the array of material handling equipment to three types most often involved in reported injuries, and combining data sources to analyze patterns of causal factors.

2. Field observations on site visits to manufacturers and users of the selected types of equipment to evaluate and verify the results of the data analysis, and to observe actual materials handling operations for a better understanding of the human factors issues involved.

3. Analysis and assimilation of the results of the above efforts to present the conclusions and recommendations of the study.

ASSESSMENT OF ACCIDENT DATA

Two specific tasks were carried out prior to the final determination of equipment types to be studied. Data from Wisconsin's Worker's Compensation case history file were used to narrow down the choices from the original twelve types specified by NIOSH in Table 3-1. Six of these accident sources each accounted for more than five percent of the total case counts for the thirteen types.

The six equipment types used in the final ranking were powered industrial trucks, powered conveyors, nonpowered hand trucks, cranes and derricks, hoists not elsewhere classified, and towing vehicles.

A second task, which justified the above choices further, consisted of preparing cross-tabulations of the accident data involving the equipment types shown in Table 3-1. Figure 3-1 gives an example of one such cross-tabulation.

TABLE 3-1
TYPES of Material Handling Equipment
to be Considered for Further Study.
CODES are those used in the ANSI Z16.2
System for Source or Agent of Injury.

ANSI CODE	TYPE OF EQUIPMENT
1301	Gravity conveyors
1350	Powered conveyors
2610	Cranes, derricks
2620	Elevators
2641	Air hoist
2642	Chain hoist
2643	Electric hoist
2644	Gin pole
2645	Jacks
5631	Hand trucks, dollies, and other nonpowered vehicles
5635	Forklift, stackers and other powered carriers
5638	Mules, tractors and other powered industrial towing vehicles

The above tasks were completed using only the computerized case history file of Wisconsin Worker's Compensation reports from the period 1972 through 1975. The relevant data for each accident report and for all cases involving a particular source of injury, are the compensation time, the healing period and the medical and indemnity costs for the case. Using the cross-tabulations for frequency and severity indices of this kind on the six equipment types mentioned, a ranking procedure was carried out to select three types for detailed study.

Figure 3-2 presents the summary ranking data used for the final determination. The measures used in ranking the hazard potential of the materials handling equipments were: case count or frequency, total compensation time, mean compensation time, total healing period, mean healing period, total indemnity cost, mean indemnity cost, total medical cost and mean medical cost, for each equipment type. Healing period and compensation time were both included since each measures severity in a slightly different way. Healing period is a variable determined by actual days away from work as a result of injury; it therefore reflects individual differences as well as employer policies of returning the injured to work as soon as possible. It is insensitive to fatalities and to other serious injuries with short healing periods but severe effects such as amputations or loss of an eye. Compensation time is a legal entity which is assigned a given value for a particular type of injury or illness: fatalities, for example, are charged with a constant 400 six-day work weeks of compensation time, under Wisconsin Law.

Figure 3-2 thus presents a combined ranking scheme which attempts to give due consideration to both frequency and severity of injuries involving the six

	Total	Falls Different	Falls To Same Level	Struck Active	Overexertion	Struck Passive	Caught-in	Vehicle Traffic	Vehicle Non-Traffic
Hoists									
Amputation									
Total	1						1		
Percent	.0						.0		
Hands	1						1		
Percent	.0						.0		
Cuts									
Total	11			1		8	1		1
Percent	.2			.0		.1	.0		.0
Head and Neck	6					5	1		
Percent	.1					.1	.0		
Trunk	1					1			
Percent	.0					.0			
Hands	1								1
Percent	.0								.0
Legs	2					2			
Percent	.0					.0			
Body Systems	1			1					
Percent	.0			.0					
Broken Bone									
Total	29	2	1	2		13	10		1
Percent	.5	.0	.0	.0		.2	.2		.0
Head and Neck	3			1		1	1		
Percent	.0			.0		.0	.0		
Trunk	2					2			
Percent	.0					.0			
Arms	1					1			
Percent	.0					.0			
Hands	8		1			3	4		
Percent	.1		.0			.0	.1		
Legs	7	2		1		1	2		1
Percent	.1	.0		.0		.0	.0		.0
Feet	8					5	3		
Percent	.1					.1	.0		
Sprain Rupture									
Total	14		1	1	6	3	2	1	
Percent	.2		.0	.0	.1	.0	.0	.0	
Head and Neck	1			1					
Percent	.0			.0					
Trunk	3				1		1	1	
Percent	.0				.0		.0	.0	
Back	5		1		4				
Percent	.1		.0		.1				
Arms	2				1	1			
Percent	.0				.0	.0			
Legs	2					1	1		
Percent	.0					.0	.0		

Figure 3-1. Example of TPL Sorting at Five Levels SIC 1500 (General Contractors-Construction for 1971-1975).

equipment types. Both total counts and mean (average) counts were felt to be crucial, since the objective was to not only compare data between these sources, but to assess the absolute or overall importance of each type as a promising source of study. The right most column in Figure 3-2 shows a count of how often a given source is ranked in the top three rankings over the nine measures used. A clear split is shown between the top three and bottom three, with powered industrial trucks, powered conveyors, and powered cranes and derricks on the top. Later analysis resulted in the combining of hoists with cranes and derricks, since Worker's Compensation accident descriptions do not clearly distinguish between the two.

Analysis Of Data For Site Visit Observations

Beyond the ranking of equipment types for final study, severity and frequency data were not used extensively. Patterns of causal factors which were revealed by the injury source--accident type cross tabulations were noted, but the limitations of data coded by ANSI Z16.2 conventions are well-known. Two sources providing more detailed information on factors leading up to the accidents were used: injured employe's descriptions of the accidents reported on promptness-of-first-payment cards (used in Wisconsin to measure performance of worker's compensation insurance carriers), and reports of investigations of selected worker's compensation claims carried out by Wisconsin safety inspectors during 1972 through 1975.

Referred to as promptness cards, the first source was gathered and sorted to compare patterns of injuries and related factors with those found earlier from the cross-tabulations of Worker's Compensation data. Since the promptness cards requested the employe's version of the accident and injury only during the year 1974, a total of 1,354 such cards were identified as implicating one of the three types of equipment. Comparison of these descriptions with those on the Worker's Compensation First Report of Injury or Illness revealed two items worth noting: first, the employe description of the accident was more likely to detail events leading up to the accident, allowing more accurate determination of agency and source of the accident; and second, this identification of agency indicated that for cranes, hoists, and powered industrial trucks, the original cross-tabulations of Worker's Compensation data underestimated the numbers of cases involving the three types. While the latter counts were based on the number of first reports referring to cranes, hoists and trucks, many cases referred only to the load dropped as the immediate source of injury, with no mention of the equipment as agency of accident. Estimates of involvement of cranes, hoists, and trucks based on employe descriptions were up to 100% higher than the original counts. This was true for conveyors also, but to a lesser extent.

Information from accident investigations for the period 1972 through 1975 provided the second source of causal factors data. The accidents investigated cannot be considered as a representative sample of those selected for study from the case history file, chiefly due to the selection procedure for investigating. The first reports of injury are screened by the inspection staff, and those cases which appear to involve the possible violation of an OSHA or Wisconsin safety regulation are singled out, as are

	CASES	DAYS				DOLLARS				
SOURCE ANSI CODE	INCIDENT FREQUENCY	TOTAL COMPENSATION TIME	MEAN COMPENSATION TIME	TOTAL HEALING TIME	MEAN HEALING TIME	TOTAL INDEMNITY COST	MEAN INDEMNITY COST	TOTAL MEDICAL COST	MEAN MEDICAL COST	# RANK 1 THRU 3 FOR SOURCE
1350 POWERED CONVEYOR	1244 (2)	34,867 (3)	28.03 (5)	21,342 (2)	17.16 (3)	469,933 (3)	377.76 (4)	227,997 (2)	183.28 (4)	6
2610 CRANES-DERRICKS	776 (4)	40,813 (2)	52.59 (1)	14,923 (4)	19.23 (1)	523,747 (2)	674.93 (1)	157,948 (4)	203.54 (1)	6
2699 HOISTS NEC.	670 (5)	21,299 (5)	31.79 (3)	10,765 (5)	16.05 (4)	232,188 (5)	346.54 (5)	127,305 (5)	190.01 (3)	2
5631 HANDTRUCKS NON-PWR.	1235 (3)	23,736 (4)	19.22 (6)	19,504 (3)	15.79 (5)	342,421 (4)	277.26 (6)	202,995 (3)	164.37 (6)	3
5635 FORKLIFT PWR.	2383 (1)	73,809 (1)	30.97 (4)	42,488 (1)	17.83 (2)	914,675 (1)	383.83 (3)	435,950 (1)	190.49 (2)	8
5638 TOWING	534 (6)	17,804 (6)	33.34 (2)	8,067 (6)	15.11 (6)	224,717 (6)	420.82 (2)	82,963 (6)	155.17 (5)	2

Figure 3-2. Values and Rankings For Six Top Equipment Sources on Hazardous Measures Potential.

most fatalities. However, the information they provided, particularly in detailing what the employe was doing when the incident occurred, was felt to be too valuable a source to omit. In spite of the possible bias, the patterns this data exhibited compared favorably with those of the worker's compensation file and the promptness cards.

Table 3-2 presents a summary of case counts covered by the various data sources.

TABLE 3-2

Numbers of cases from each source for each equipment type (1972-1975)

	Equipment Type		
Data Source	Powered Industrial Trucks	Powered Cranes and Hoists	Powered Conveyors
Worker's Compensation Case History File	3,087	1,646	1,255
Employe Accident Descriptions (Promptness Cards)*	662	413	279
Accident Investigation Reports	91	76	386

*1974 only

As Table 3-2 illustrates, large numbers of cases formed the basis for the analysis, but the data on causal factors from the last two sources covered only from 25% to 50% of the reported cases. Conveyor related cases were investigated much more often due to the potential for finding a violation of a safety regulation. The details of this data are presented in the relevant chapters.

To plan the site visits for verification and refinement of the causal factors patterns, cases were sorted into categories roughly determined by the accident type within the source (equipment). For each category, promptness cards and accident investigations were analyzed and the factors sorted to indicate possible human factors deficiencies in the design or operation of the equipments studied. Checklists were constructed from these and were used on the site visits as focal points for observing actual operations. The basic contents of these, which varied somewhat depending on the plant visited, are presented in the following chapters.

FIELD OBSERVATIONS

Site visits were planned using the data analyzed as described above. Wisconsin business establishments with large numbers of reported Worker's Compensation cases involving the three equipment types, and those suggested by equipment dealers and manufacturers, were listed as possible candidates for site visits. Visits were actually made to major manufacturers of each equipment type, to users of each, and to a small number of dealers and conferences pertinent to the project.

Visits to Manufacturers

Site visits were made to several major manufacturers of cranes, hoists, conveyors, and powered industrial trucks in and out of Wisconsin. The intention was to determine to what extent designers and makers of material handling equipment incorporated human factors design principles into their machines. While a large percentage of the accidents used as the basis for the research might be due to design features and operational features of older, sometimes obsolete equipment makes and models, manufacturers' current practices and objectives in this area were felt to be critical to an overall understanding of the process.

A second objective was to discuss accident and hazard patterns with manufacturers, dealers and accessory sales people to determine the extent to which they had knowledge of hazards, and had developed instruments in their own plants and for users of their equipment to detect and manage hazards associated with their machines. We surmised that in manufacturers' plants, especially where conveyors, industrial trucks and cranes and hoists were used extensively, specialized techniques for controlling and managing hazards might be found.

Businesses in this category which were visited included two prominent manufacturers of cranes and hoists, and a dealer for manufacturers of chains, slings, wire ropes, hooks and other crane and hoist accessories; two manufacturers of conveyors and conveyor systems; one manufacturer of powered industrial trucks, and a dealer for a second truck manufacturer. Several discussions were held with other industrial truck makers at a meeting of the International Standards Organization, Technical Committee 110 Subcommittee on Powered Industrial Trucks. This meeting also afforded researchers the opportunity to talk with representatives of European industry and government concerned with industrial truck safety.

The discussions held with the manufacturers and others typically centered around questions of their perceptions of the need for human factors and ergonomics in truck, conveyor and crane design. An effort was made to determine how manufacturers and dealers saw their own responsibilities in the areas of collecting data on accidents involving their equipment, of informing dealers, buyers, and other users of possible hazards in the use/misuse of their equipment, and of modifying product design when accident data seemed to warrant a change. They were also asked to comment on the injury patterns shown by the worker's compensation data analysis, and on the relation between these and the existing relevant OSHA and ANSI Standards.

As manufacturers, dealers and others doing business with users were interviewed first, the results of these discussions helped in refining the questions to be asked of users.

Visits to Users

Companies were selected as candidates for possible visits on the basis of their reported Worker's Compensation case experience. Computer lists were generated showing all employers who had reported injuries or illnesses involving cranes, conveyors or industrial trucks, and those plants with large numbers of such cases were contacted by telephone. In addition, several visits were made, at the suggestion of a manufacturer or dealer, to plants which were believed representative by the latter.

After arrangements were made by telephone, a team of four to six researchers, including one of the human factors consultants, visited the plant for on-site observation of the selected equipment types in use. The visits typically began with a discussion with management and worker representatives to clarify our objectives and to identify operations in the plant for detailed study and possible photography. At these meetings, the accident patterns indicated by the Worker's Compensation data were discussed, specific areas in which to look for hazards were noted, and individual management, supervisory, or working people were named as good sources of information.

The observations of equipment in use were then made during walk-through tours of the plant. Where feasible, researchers interviewed workers and supervisors to clarify issues that came up, or to obtain information not available elsewhere.

The basic structure of the observations made during these visits was based on the identification of hazards involved in the use of cranes, trucks, and conveyors; the main sources for identifying these were the original accident data analyses, worker and supervisor comments, and the researcher's observations themselves. In addition to information regarding the immediate hazard, an understanding of peripheral factors, including organizational and behavioral, was obtained through questioning of plant personnel and observation.

Based on the original analyses, each equipment type and its associated problems demanded slightly different kinds of information. Below are listed, for each type of equipment, the main points that were addressed once a hazard had been identified.

For powered industrial trucks:

.Truck operator data--job title, experience on present job, type and make of truck involved, average time per day spent driving or working with the truck, kind and amount of training the individual had been given, nature of tasks involving the trucks.

.Task and machine characteristics--peculiarities of the truck itself, load characteristics, general work site description.

.Comments on specific hazards noted earlier--loads falling off the truck, pedestrian traffic problems, riding on the forks or the load, trucks tipping or overturning, running into things, adjusting the forks or working on the truck, loading and unloading semis or railroad cars, other hazards.

For powered cranes and hoists:

- .Employe data--occupation, experience on present job, description of job situation including equipment used, physical layout, housekeeping factors, main tasks of the job, proportion time spent using cranes or hoists, type of training received.

- .Specific hazards--for each of the appropriate following conditions, information was sought on what specific hazards was the interviewee faced with, and what was done to control these hazards: loads falling when lifted, manually handling and attaching, or moving loads on hoists and cranes, getting hands caught in hoist or load, hoists or cranes malfunctioning, maintenance operations on cranes or hoists, availability of proper equipment and accessories.

For powered conveyors:

- .Employe data--occupation, experience in present job, equipment used, description of environment, nature of work situation, main tasks of job, time spent working near or with conveyors, type of training received for the job.

- .Data on specific hazards: caught in accidents, guarding of conveyor nip points and other problem areas, lockouts, emergency stops, color coding of pinch points, source of pinch points, maintenancing, unjamming, over-exerting, being struck by conveyed objects, climbing over or under conveyors

For all of the above, when a hazard had been identified by a worker or supervisor, the person was asked how he or she attempted to control the hazard or avoid its causing an accident, and also what suggestions did he or she have for improving the situation.

Photographs were taken to illustrate a particular operation or use of an equipment type, when the employer had no objections.

ANALYSIS OF FIELD DATA

In depth study and discussion of the findings revealed a basic organization among the perceptions of hazards and the judgments about their causes and controls. This is the sequence of events and conditions which, beginning with the design of a piece of equipment and leading to a specific task, defines and creates a particular hazard. Grether (1975) touches on this, and Cherns (1977) and others of the socio technical school (Davis & Trist), have long recognized the need for attention in the design phases to probable outcomes. The present analysis provides evidence that accident causes and hazards come and go at all stages of the design-to-ultimate-use process, where failure to institute countermeasures in an early phase results in greater risk and possibly more costly controls at a later stage.

The first step in the analysis was to categorize most of the information gathered during field visits. The unit of analysis was a specifically

GENERAL FUNCTION OF TASK	REMOTE MANAGEMENT PRE-OPERATION & PLANNING SUMMARY	AT-SITE SUPERVISOR AND EMPLOYEE PRE-OPERATION & PLANNING SUMMARY	TASK SPECIFIC FACTORS AND BEHAVIORS SUMMARY	AT-SITE TASK FOLLOW-UP SUMMARY	OVERALL SUPPORT FUNCTIONS SUMMARY
SUPERVISOR - DIRECTS A CREW OF 4 FULL-TIME & 2 PART-TIME MEN INVOLVED IN CRANE MAINTENANCE IN THE PLANT.	BECAUSE THE PLANT IS NON-UNION, MAINTENANCE MEN CAN OPERATE CRANES TO EVALUATE MAINTENANCE PROBLEMS - THEY DON'T HAVE TO BE UNION CERTIFIED TO OPERATE THE CRANE.	BEFORE STARTING, EACH OPERATOR IS SUPPOSED TO OPERATE THE VARIOUS CONTROLS OF THE CRANE TO CHECK CONDITIONS AND TO REPORT ANY OPERATIONAL PROBLEMS TO MAINTENANCE.	CRANE SLIPPING PROBLEMS AND OTHER PROBLEMS IN LACK OF SMOOTH OPERATIONS CAN DEVELOP FROM WEAR ON THE CRANE TRACKS OR HOIST DRUMS.		REGULAR MONTHLY INSPECTIONS OF CRANES DETECT THE DEVELOPMENT OF MAINTENANCE PROBLEMS & THESE ARE QUICKLY SCHEDULED FOR REPAIR. THESE INCLUDE CHECKS OF HOISTS, CONTROLS, REAVINGS, ETC.
MAINTENANCE PERSONNEL WHO WORK THROUGHOUT THE PLANT COMPLEX DOING CRANE MAINTENANCE AND REPAIR ON ALL HOISTS, OVERHEAD AND MOBILE CRANES.	THERE IS A RED FLASHING LIGHT ON EACH OVERHEAD CRANE WHICH IS TURNED ON WHEN THE CRANE IS DOWN FOR REPAIRS TO KEEP OTHER CRANES AWAY.	BEFORE PERFORMING MAINTENANCE ON ONE CRANE IN A BAY WITH OTHERS, THE RED LIGHT IS TURNED ON WHEN THE WHOLE BAY CAN'T BE LOCKED OUT OF SERVICE.	WHILE OUT OF COMMISSION FOR MAINTENANCE, A BRIDGE CRANE IS VULNERABLE TO OTHER CRANES OPERATING IN THE SAME BAY, AS ARE THE MAINTENANCE MEN. FINGERS AND HANDS CAN GET CAUGHT IN THE CABLES WHILE WORKING ON THE DRUMS AND HOISTS.		
	CRANE OPERATORS AREN'T ALWAYS WELL INFORMED ON KEEPING CLEAR OF CRANES WITH RED FLASHING LIGHTS. HE FEELS MORE EMPHASIS IS NEEDED ON THE RED LIGHT RULE.	TO AVOID CAUGHT-IN OR FALLING INJURIES DURING MAINTENANCE HE REMOVES HIS GLASSES. IF THEY FELL OFF, HE FEELS HE MIGHT LUNGE FOR THEM AS A REFLEX ACTION.			

Figure 3-3. Sample analysis sheet for hazard information.

identified hazard. When several hazards appeared to arise during a specific task, they were grouped under the general description of the task. Figure 3-3 is an example of the hazards and related factors found to be associated with the tasks shown.

The information gathered was found to be largely describable using the six headings shown in Figure 3-3. According to this scheme, each hazard (Task Specific Factors and Behaviors), such as a falling load or a truck tipping, occurs during the task listed in the left most column. The next column details those physical factors and design features usually decided upon by management, while the third column (AT SITE SUPERVISOR AND EMPLOYE PREOPERATION PLANNING SYMMARY) served to record factors controllable just before the particular taks or task cycle was to be started. Both preventive steps and perceived obstacles to prevention, or simply known factors contributing to the hazard, were detailed here.

Columns 5 and 6 provided for information about correcting hazards arising during the task, and about overall management support, usually maintenance activities.

While some judgment on the researcher's part was necessary in categorizing the information, the great majority of hazards were explainable in these terms. Few had entries in every column; some, depending almost totally on worker behavior during the task, were completely described in column 4 (TASK SPECIFIC FACTORS AND BEHAVIORS). Others, particularly purely physical hazards, dangerous to anyone doing the task, are described totally in column 2.

The final report was written using these summaries and other more global data resulting from the visits. This included the OSHA and ANSI Standards relevant to materials handling equipment, information on general safe practices obtained from manufacturers, dealers and accessory sales personnel, and the general safety and health literature.

CHAPTER 4. POWERED INDUSTRIAL TRUCKS

BEGINNING

This chapter is about the human factors that contribute to accidents and hazards involving powered industrial trucks. Design deficiencies in these material-handling devices are discussed, and shortcomings in ergonomic design in particular are pointed out. In addition, several factors are discussed at length that are concerned with the interface between the performance of one human task and the performance of a related human task. These matters and some others as well are included in the concept of human factors that guided this study, along with ergonomics.

An inspection of the Workers' Compensation records of industrial-truck accidents in Wisconsin 1972-1975 showed what were the most crucial kinds of accidents for each of four kinds of truck: sitdown rider-controlled trucks, pedestrian-controlled powered trucks ("walkie" trucks), front-end loaders, and standup rider-controlled trucks. Causal information related to these Worker's Compensation cases revealed some important patterns of accident-occurrence for the different kinds of trucks. The findings from the Workers' Compensation investigations yielded the list of topics to be studied in the field.

During the observations of equipment in use and during the many conversations we had with powered-industrial-truck drivers, pedestrian co-workers, mechanics, plant engineers, plant managers, truck salesmen, truck-makers' engineers, and safety officials, all relevant factors were sought after, largely in order to gain an insight into the importance of ergonomics relative to other factors. Preliminary findings indicated that workers involved in industrial-truck operations are often highly experienced, but usually have had rather little training. We also found the vast majority of trucks in use to be surprisingly old. Given the size and prominence of the firms we visited, we suspect that our sample was above national means and medians with respect to worker training and experience and below the national means and medians with respect to truck age.

On analysis of the field-data, thirty-eight factors were found to be common contributors to forklift hazards. The most important of these are discussed at length in this chapter (See also figure 4-8): backing up with the truck, turning corners, establishing and maintaining communication among workers in shared tasks and spaces, and blocking wheels on semi-trailers; requesting/giving rides on the load, bare forks, or empty pallet, the condition of the load, and the condition of the driving surface; crowded cluttered aisles, maintenance & age of the trucks, and training of workers involved in industrial-truck operations. Problematic truck features discussed include malfunctions and design-weaknesses related to these, inadequate safety devices, visibility, and such human-factors design weaknesses as make-to-make differences in the means of actuating service-brakes on standup rider trucks, cramped driver compartments, and hard seats that may also lack thigh-support and lower-back support.

OSHA and ANSI standards related to the thirty-eight factors were examined, and it would appear that most of the factors are addressed both by clauses of standards and by emphasis during OSHA inspections. Some points not addressed by clauses of the standards are also claimed to be inappropriate matters for standards writing. Some rather minor changes are suggested for existing standards, however.

Possible subjects for further fruitful study are intimated in all phases and levels of interest in forklift operations. There are issues of interest for the sake of scientific understanding of forklift hazards; other issues are related to the goal of further clarifying standards and establishing guidelines by which employers and drivers can comply with the standards; some other topics seem helpful toward equipping inspectors to identify the crucial hazard-making factors at their points of origin. Other topics yet would be important for direct accident-prevention efforts by plant managers and by truck-designers. And there are some items of research-and-development interest directed toward raising the state of the trade in the ergonomics of trucks in use.

This study yields some important conclusions: (1) ergonomics, or any other rather small set of factors, cannot at this juncture be shown to be a primary element in the etiology of forklift hazards and accidents in general. There are too many factors, too many ways in which they can combine to produce hazards and accidents, and too many conditions that vary too widely from one plant to the next. Nonetheless, ergonomics cannot be dismissed from attention. (2) there are therefor no simple causes and hence no simple solutions for the Industrial Truck Safety Problem.

(3) the safe and effective performance of material-handling tasks using powered industrial trucks depends upon the way in which vast numbers of persons over whom drivers of industrial trucks usually have little or no influence perform tasks distinct from but related to the material-handling tasks. These tasks include both the design of trucks and decisions about bases of pay within the plant. Thus forklift operations actually constitute a nation-wide system consisting of huge numbers of sub-systems of interrelated human activity. Individual elements of the system can break down, and the system is rather poorly integrated.

(4) the human factors in forklift hazards and accidents are the interfaces among all the subsystems of human activity that make up the industrial-truck operations system.

ANALYTICAL STEPS AND PRELIMINARY FINDINGS--WORKERS' COMP. RECORDS

When it was determined that powered industrial trucks were to be one of the three kinds of materials-handling equipment to be investigated in this study, it was decided to divide this category of equipment into four sub-types; sitdown rider trucks, standup rider trucks, pedestrian-controlled powered industrial trucks (referred to hereafter in this report as "walkie" trucks), and front-end loaders. This last variety of materials-handling equipment was included because they are somewhat similar to forklift trucks, in that they travel on tires rather than crawlers, they engage, lift, transport, and deposit loads of materials, the main difference in the loads being that front-end loaders carry material in bulk rather than items in containers on pallets or skids; it is also the case that the Wisconsin Workers' Comp. coding system does not adequately distinguish between the small bobcat-type trucks used indoors in foundries from the larger earth-moving trucks used outdoors.

It was decided to analyze data for these four different kinds of trucks separately on the reasoning that the notable differences in the configurations of these different kinds of truck would likely be associated with different kinds of accidents. To some extent, this assumption was borne out by the subsequent analysis.

Data recorded on the Workers' Comp. Case History File were analyzed to compare the frequency and severity of powered-industrial-truck accidents to the average of all Workers' Comp. cases, and of each kind of truck to the other kinds of trucks. Figure 4-1 shows the results of this analysis. It was found, for instance, that accidents involving powered industrial trucks in general account for about 1.6% of all the W-C cases 1972-75, and were somewhat more severe than average. Accidents with sitdown rider trucks were far more frequent than accidents with other kinds of trucks, and were more severe than those involving standup rider trucks and walkie trucks.

Figure 4-1

POWERED INDUSTRIAL TRUCKS VS. ALL ACCIDENTS
'72 - '75

Source	Count*	Total Money Paid*	Mean Money Paid	Total Healing Days*	Avg. Hlng. Days	Total Comp. Days*	Avg. Comp. Days
All W-C Cases	196,612	$127,734,236	$650	3,789,190	19	6,294,276	32
All Powered Industrial Trucks	3,087 (1.6%)	2,118,082 (1.7%)	686	66,001 (1.7%)	21	109,880 (1.7%)	36
Sitdown Rider Forklifts	2,523 (1.3%)	1,720,119 (1.3%)	682	53,815 (1.4%)	21	87,512 (1.4%)	35
Standup Rider Forklifts	224 (0.1%)	131,625 (0.1%)	588	4,609 (0.1%)	21	6,031 (0.1%)	27
Walkie Trucks	96 (<0.1%)	46,151 (<0.1%)	481	1,771 (<0.1%)	18	2,380 (<0.1%)	25
Endloader or Payloader	236 (0.1%)	217,709 (0.2%)	923	5,685 (0.2%)	24	13,845 (0.2%)	59

*percentages using the first figure in the column as a base.

Accidents involving endloaders were much less frequent, but notably more severe.

Next the frequency of several accident-types was analyzed, and the involvement of each kind of truck in each sort of accident was compared both with the total for all kinds of trucks and with the other kinds of trucks. Figure 4-2 shows the results of this analysis. It was found, for instance, that accidents in which someone was struck by items falling from the truck were proportionately less frequent for standup rider trucks and walkies than for sitdown rider trucks. By contrast, it was found that accidents in which someone was pinned between the truck and a stationary object were proportionately much more frequent for standup rider trucks and walkies than for sitdown rider trucks, as were accidents in which the operator was struck by the truck he was maneuvering.

Next the fatalities involving powered industrial trucks were investigated. Five deaths were associated with sitdown rider trucks, and six with endloaders, thus bearing out the earlier finding that these kinds of trucks are involved in the more serious accidents than the other two types. Since there were so few fatalities in relation to the total number of accidents, the associated accident-types were noted, but further analysis was eschewed. Figures 4-3 shows the results of this analysis.

Next the accident-data for each of the four kinds of truck were analyzed according to accident-type, to learn the frequency and severity of each major kind of accident for each kind of truck. Within each kind of truck, accident-types were assigned a rank according to the following method: The severity-measures of mean W-C benefits paid per case, mean healing days per case, and mean comp. days were calculated, and each accident-type was assigned a rank in descending order on each of these measures. The three severity-measure-ranks for each accident-type were averaged. Then the accident-types were ranked in descending order on case-counts. The average of the severity ranks for each accident-type was then averaged with the frequency-ranking to produce an overall ranking that attempts to give frequency and severity equal weight. Figures 4-4, 4-5, 4-6 and 4-7 show the results of this analysis. It turns out that the top three accident-types for sitdown rider trucks were: someone is struck by material from the truck, someone is pinned between the truck and a stationary object, and third, someone is struck by a moving part of the trunk. For walkie trucks, the top three were: a pedestrian is struck by the truck, overexertion-type injuries, and someone falls onto or against the truck. For endloaders, the order was: pedestrians struck by the truck, someone is struck by a moving part of the truck, and someone is struck by material from the truck. For standup rider trucks, the order is

TABLE OF PREDOMINANT LIFT-TRUCK ACCIDENTS: TYPES AND SOURCES

	All Powered Trucks	Sit-Down Rider Trucks*	Standup Rider Trucks*	Walkie Trucks*	Endloader or Payloader*
ALL TYPES	3,079	2,523	224	96	236
Struck by material from lift-truck	218 (7%)	201 (8%)	5 (2%)	3 (3%)	9 (4%)
Caught between moving & stationary object	432 (14%)	346 (14%)	55 (25%)	16 (17%)	15 (6%)
Struck by moving part of forklift	493 (16%)	422 (17%)	18 (8%)	1 (1%)	52 (22%)
Struck pedestrian (in the plant)	711 (23%)	617 (24%)	46 (21%)	20 (21%)	28 (12%)
Truck overturns or tips	39 (1%)	33 (1%)	0	0	6 (3%)
Collision with stationary object	215 (7%)	166 (7%)	24 (11%)	2 (2%)	23 (10%)
Fell from lift-truck	84 (3%)	63 (2%)	7 (3%)	1 (1%)	13 (6%)
Overexertion	148 (5%)	108 (4%)	10 (4%)	23 (24%)	7 (3%)
Caught in or struck by mechanical parts	59 (2%)	36 (1%)	12 (5%)	0	11 (5%)
Bumped into or fell against	312 (10%)	243 (10%)	16 (7%)	7 (7%)	46 (19%)
Mechanical failure	18 (1%)	17 (1%)	1 (0.4%)	0	0
Fell with lift-truck	11 (0.4%)	10 (0.4%)	0	0	1 (0.4%)

Table of Predominant Lift-Truck Accidents - P. 2

	All Powered Trucks	Sit-Down Rider Trucks	Standup Rider Trucks	Walkie Fork Trucks	Endloader or Payloader
Collision with moving vehicle	26 (1%)	20 (1%)	5 (2%)	0	1 (0.4%)
Struck by object handled by injured	57 (2%)	30 (1%)	12 (5%)	14 (15%)	1 (0.4%)
Load shifted	12 (0.4%)	12 (0.5%)	0	0	0
Sudden stop	18 (1%)	11 (0.4%)	1 (0.4%)	1 (1%)	5 (2%)
Other types	226 (7%)	188 (7%)	12 (5%)	8 (8%)	18 (8%)

*Percentages using the first figure in each column as a base.

Figure 4-3

TABLE OF FATAL ACCIDENTS INVOLVING POWERED INDUSTRIAL TRUCKS

	Sitdown Riding Fork Trucks	Endloaders or Payloaders
Pedestrian struck by industrial - truck	1	1
Caught in or struck by mechanical part of truck	1	1
Fall with truck	1	0
Struck by another vehicle	1	0
Struck by material from lift truck	1	1
Electrocution	0	1
Caught between a moving and a stationary object	0	2
TOTAL	5	6

Figure 4-4

SITDOWN RIDER FORK TRUCKS - PREDOMINANT ACCIDENT TYPES
ACCORDING TO COMBINED FREQUENCY & SEVERITY

Accident Type	Case Count	Total Money Paid	Mean Money Paid	Total Healing Days	Mean Healing Days	Total Comp. Days	Mean Comp. Days	Rank
ALL TYPES	2,523	1,720,119	682	53,815	21	87,512	35	
Struck by material from forklift	201	172,428	1,626	5,678	28	17,120	85	1
Caught between forklift & stationary object	346	292,823	846	9,758	28	14,527	42	2
Struck by moving part of forklift	422	278,569	660	8,640	20	13,585	32	3
Truck strikes pedestrian (in the plant)	617	372,325	603	11,796	19	16,907	27	4
Forklift tips	33	32,671	990	913	28	1,759	53	5
Collision with stationary object	166	90,646	855	3,332	20	4,069	25	6
Fell from forklift	63	59,756	949	1,054	17	4,137	66	7
Overexertion	108	80,218	743	1,932	18	4,357	40	8
Caught in mechanical parts or struck by mechanical parts	36	28,046	779	627	17	1,968	55	9
Bumped into or fell against	243	99,697	410	3,645	15	4,423	18	10
Mechanical failure	17	11,765	692	442	26	430	25	11
Fell with forklift	10	7,119	712	213	21	608	61	12
Collision with moving vehicle	20	12,697	635	386	19	602	30	13
Struck by object handled by injured	30	7,204	240	366	12	324	11	14
Load shifted	12	4,198	350	175	15	170	14	15
Sudden stop	11	3,817	347	166	15	154	14	16
Other types	188	166,140	884	4,692	25	2,372	13	

Figure 4-5

PEDESTRIAN-CONTROLLED POWERED INDUSTRIAL TRUCKS ("WALKIE" TRUCKS)

PREDOMINANT ACCIDENT TYPES ACCORDING TO COMBINED FREQUENCY AND SEVERITY

Accident Type	Case Count	Total Money Paid	Mean Money Paid	Total Healing Days	Mean Healing Days	Total Comp. Days	Mean Comp. Days	Rank
ALL TYPES	96	46,151	481	1,771	18	2,380	28	
Pedestrian struck in plant	20	19,176	959	745	37	1,023	51	1
Overexertion	23	17,892	778	564	25	929	40	2
Fell onto or against truck	5	1,133	227	74	15	77	15	3
Struck by object handled by injured	14	2,458	176	118	8	98	7	4
Collision with stationary object	2	1,149	575	48	24	67	34	5
Caught between a moving and a stationary object	16	2,264	142	110	7	89	6	6
Sudden stop	1	463	463	26	26	26	26	7
Struck by moving part of truck	2	300	150	22	11	19	10	8
Bumped into truck	2	494	247	15	8	12	6	9
Struck by load falling from vehicle	3	0	0	0	0	0	0	10
Other types	8	822	103	49	6	40	5	-

Figure 4-6

TABLE OF ACCIDENTS INVOLVING ENDLOADERS

Accident Type	Case Count	Total Money Paid	Mean Money Paid	Total Healing Days	Mean Healing Days	Total Comp. Days	Mean Comp. Days
ALL TYPES	236	217,709	922	5,685	24	13,845	59
Pedestrian struck by endloader	28	56,982	2,035	699	25	4,043	144
Struck by moving part of endloader	52	32,732	629	1,204	23	1,670	32
Struck by material from endloader	9	16,724	1,858	416	46	3,191	396
Fell from endloader	13	17,098	1,315	523	40	991	76
Caught in or struck by mechanical parts of endloader	11	20,729	1,884	472	43	744	68
Caught between a moving and a stationary object	15	12,413	828	502	33	634	42
Bumped into endloader	25	11,524	461	487	19	556	22
Fell against endloader	21	10,696	509	402	19	455	22
Collision with a stationary object	23	7,401	322	224	10	191	8
Overexertion	7	8,565	1,224	196	28	496	71
Sudden stop	5	7,095	1,419	197	39	449	90
Endloader tips	6	4,969	828	162	27	237	40
Various other types	21	10,781	513	201	10	188	9

Figure 4-7

STANDUP RIDER FORKLIFTS - TABLE OF PREDOMINANT ACCIDENT TYPES ACCORDING TO COMBINED FREQUENCY AND SEVERITY

Accident Type	Case Count	Total Money Paid	Mean Money Paid	Total Healing Days	Mean Healing Days	Total Comp. Days	Mean Comp. Days	Rank
ALL TYPES	224	131,625	588	4,609	21	6,031	27	
Pedestrian struck in plant	46	35,268	767	1,226	27	1,637	36	1
Collision with stationary object	24	29,453	1,227	733	31	1,582	66	2
Caught between a moving and a stationary object	55	30,378	552	1,256	23	1,277	23	3
Struck by moving part of truck	18	11,553	642	421	23	558	31	4
Struck by object handled by injured	12	5,629	469	265	22	256	21	5
Struck by load falling from vehicle	5	2,899	580	90	18	159	32	6
Collision with moving vehicle	5	2,699	540	116	23	143	29	7
Caught in parts of lift truck	12	2,071	173	91	8	85	7	8
Fell from equipment	7	1,732	247	78	11	69	10	9
Mechanical failure	1	1,337	1,337	16	16	16	16	10
Overexertion	10	2,573	257	81	8	66	7	11
Bumped into truck	11	2,485	226	91	8	71	6	12
Fell against lift truck	5	1,324	265	41	8	35	7	13
Other types	13	2,224	171	104	8	77	6	

shuffled again: pedestrians are struck by the truck, the truck collides with a stationary object, and someone is pinned between the truck and a stationary object.

Next, part-of-body-affected and nature-of-injury data were examined and recorded for each major accident-type within the kind of truck involved. (See McPeek, 1976)

Then records of accident-investigations by Wisconsin inspectors, and injured workers' descriptions of their accidents were matched to truck-type and accident-type to gain causal information. Great problems in matching were encountered, however, (see above Chapter 3) and for this reason further statistical analysis was abandoned. Simple counts were relied upon instead to indicate the significance of important patterns of accident-occurrence. It is interesting to note, however, that the causal reports indicate the true involvement of powered industrial trucks in accidents on the job may be as much as twice as great as what is recorded on the Wisconsin W-C Case History File.

The causal information reveals that loads fall off sitdown rider trucks and strike bystanders somewhat more often than they strike helpers and drivers. It is noteworthy also, that attachments and overhead canopies themselves fall off the truck about half as often as the load falls on a bystander. Forks have a tendency to fall off the truck as well. Drivers of these trucks pin pedestrians against stationary objects, but they also pin their own extremities rather often as well. The major pattern with respect to persons struck by a moving part of the truck turns out to involve co-workers resting hands on part of the lift mechanism while riding on the forks or the load or an empty pallet, or while standing and talking with the driver. (for other interesting patterns related to the remaining accident-types, see McPeek, 1976)

With respect to pedestrian injuries involving walkie trucks, the causal information was rather unenlightening. In the case of the overexertion-type injuries, it was found that these involved the operator maneuvering his truck. The falls onto or against walkie trucks turned out to be drivers who slipped on a poor walking surface. (for further information, see McPeek, 1976)

The causal information regarding endloader-accidents was quite unenlightening as regards pedestrian accidents, and those accidents in which someone is truck by a moving part of the truck. The load-falling-off accidents, however, seemed to involve the use of the endloader's bucket as a small powered hoist, with the load poorly arranged and poorly hitched. (cf. Chapter 5 below).

Such little causal information as could be strictly matched with standup rider trucks with regard to pedestrian accidents and collisons with stationary objects revealed no clear patterns of accident-occurrence. In the case of pinning someone against a stationary object, however, it became clear that this happened mostly to the truck's own driver. The most important contributing factor seemed to be problems the driver encountered in backing the truck up; in 3 cases, the driver appeared to have been dangling a lower extremity out the back of the truck.

METHODS AND PRELIMINARY FINDINGS IN THE FIELD.

It became clear early on in our attempts to contact plants to visit for observation of powered industrial trucks in action that we would be unable to choose plants according to type or make or model of truck we might wish to observe. We also wanted to view as wide a variety of makes and models and attachments as possible. (Cf. above, Chapter 3).

Accordingly, it was decided to draw up a list of topics for dicussion with workers and plant engineers and plant managers that would apply to industrial trucks quite generally; we decided also that the list of topics would need to be as brief as possible. The actual list is given above in Chapter 3.

We asked our discussants to talk about hazards and factors that could contribute to accidents, and we deliberately broached topics in a very broad, general manner. We did not ask them directly about accidents. This was done to elicit as wide a range of information as possible in as non-threatening a way as possible. This approach is called for by the model of hazard management that guided this study from its outset. (see above, Chapter 2, and Coleman and Smith, 1976). Some degree of content-validity of worker-mentioned hazards was assured by conducting our conversations at or very near the site of our discussants' tasks, so that workers could demonstrate the problems they talked of.

The W-C causal information and some previous experience had indicated that, if there is any such thing as the Average Industrial Truck, it is a sitdown rider truck powered by a gasoline or LP Gas engine, of two or two-and-a-half ton capacity. We suspected that standup rider trucks (mostly electric powered) and walkie trucks (almost all electric) would be found in numbers equal to each other, but each less common than the sitdown rider truck. Less frequently used yet, we surmised, are side-loading fork trucks and order-picker trucks. We were very fortunate that we were able to observe trucks in just about those proportions, despite our limited ability to pre-select trucks for observation. Half of the trucks we observed were sitdown rider trucks, most of them LPG powered; 18% were standup rider trucks, 18% were walkies, 13% were order-picker trucks, and we observed one side-loader. We had occasion to watch in action 2 different kinds of clamp-attachment, fork extensions, push-pull attachments, and reach-scissors attachments.

We observed operations and talked with workers about industrial-truck hazards in twelve different plants in seven firms with different operations: three were essentially warehouses, and the other nine were manufacturing plants. The warehouses handled different kinds of goods: one is a central warehouse for a chain of retail food stores, one is the shipping facility for finished goods in a firm that manufactures aluminum wares, and the third is a non-store retail distribution center for a large mail-order firm. The manufacturing plants include a maker of non-powered hand tools, an alumimun-rolling mill, a maker of brass fixtures, a milling-and-assembly plant for engines that power electric generators, an iron foundry, a canner of carbonated soft drinks, a maker of vitreous-china goods, a maker of corrugated-board containers, and a crew that functioned as a centrally-dispatched group for unloading incoming raw materials at various buildings in the firm.

We talked with 146 workers: 22 drivers of industrial trucks in loading-dock operations, 62 industrial truck drivers engaged in supplying and picking up from production work-stations, 40 industrial-truck drivers engaged in warehousing operations (transporting good from receiving to storage, placing goods in stacks and racks, rotating warehouse stock, selecting items for shipping orders, transporting goods from storage to shipping), 11 pedestrians working as production workers or clerks who have occasion to interact with industrial trucks, and 11 mechanics who maintain the trucks.

We observed 110 individual trucks of at least 10 different makes spanning the alphabet from Allis-Chalmers to Yale, and in very few instances were several trucks of the same model and make and vintage.

We found two things rather remarkable about our discussants: (a) they tended to be quite experienced; (b) they did not always receive much training. The range of experience was from less than 3 months in one case to more than 30 years in another, but the average was 8 years in driving or interacting with powered industrial trucks. Only 7% of our discussants had less than a year's experience in the tasks demanded by their present jobs, and 25% of them had had 10 years' experience or more. Since a recent study shows the critical experience-value to be 0-12 months (Hart 1976) no analysis of hazards by experience of discussant was attempted. We also found no important connection between length of experience and value of the information offered.

We found that only 23% of the drivers we talked with had received formal training for their industrial-truck tasks, and the number of hours in the classroom varied from 1 (taken up by a written test and not by instruction) to 16; some programs were administered at the plant, some by local vocational schools, and some by truck-manufacturers. Some training programs were spread over a 4-week period, and some were concentrated into two days. Not all programs included written tests, and only one included a "road" test. Some training was administered as much as two years after the drivers had begun operating industrial trucks. Only one plant we visited had a regular program of re-training and re-certification of industrial-truck drivers.

Not all programs included supervised practice with the trucks.

About forty-four percent of the drivers we talked with said that they had received on-the-job training. The training tended to consist of an explanation or demonstration of the controls of one kind of truck the trainee would be using by a supervisor or experienced worker. But the amount of supervised "practice" varied from 15 minutes of loosely supervised regular tasks to as much as 10 days of rather closely supervised "light" tasks under low-presssure conditions. The amount of supervised "practice" did not appear related to previous experience: only a tenth of those who received on-the-job training said they had had previous experience, and even then that experience was often with farm tractors, not industrial trucks.

Somewhat more distressing is the fact that fully 34% of the drivers we talked with said they had had no training, and only a tenth of these had had any previous experience. This experience, too, was with farm machinery, not industrial trucks. Included in this 34% are almost all of the walkie operators, who appear to receive training in only the rarest cases.

Several of the mechanics had had many long years of experience in repairing industrial trucks, and a little less than half of them had completed courses in automobile repair at vocational schools. Only one had received training specifically for industrial trucks, and he had been a field-service man for a local industrial-truck dealer before joining his present firm.

The pedestrian workers we talked with had received no training for those portions of their tasks that involve interaction with powered industrial trucks. It appears that no one receives any training emphasis in defensive walking in the plant.

We also found that, in spite of the size and prominence of the firms we visited, they tend to keep their trucks in use for quite a long time. Hardly any of the trucks we observed were known to be less than 18 months from the dealer, and the vast majority were 5 years old or more. In one plant, this researcher observed in operation a truck with over 90,000 hours on its meter--equivalent to nearly 10 years' constant use without interruption even for refueling. The truck was said to be given intermittent use daily. In the same plant, at least one other truck was observed that had over 70,000 hours on its meter. In another plant, trucks were observed in regular daily use hauling melt from furnaces to pouring stations in a foundry. It was not known precisely how old these were, but they were thought to be of World War II vintage.

In some other plants, trucks presented a very battered and battle-scarred appearance, with almost all nameplates long since gone. These were suspected to be at least ten years old, if not more. The plant that appeared to have the lowest average age of truck owned none more than eight years old--but the plant itself was barely eight years old at the time of our visit.

It would appear, then, that the real world of industrial-truck operations is dominated by large numbers of very old trucks. This would tend to suggest much in terms of the likelihood of truck malfunctions, difficulties in maintaining the trucks in top operating condition, and the state of the art of ergonomic design of trucks as drivers actually encounter it.

SOME COMMON FACTORS

Notes from the field observations and from the conversations with drivers of industrial trucks, pedestrian workers, plant engineers and safety personnel and managers, were analyzed with respect to the hazardous event to which the discussant felt the factor he mentioned contributes. There were some eighteen categories of such events and these are, in descending order of frequency of mention: (1) the load falls off the truck; (2) pedestrian is struck or pinned by the truck; (3) collisions in general; (4) the truck tips; (5) driver loses control of the truck; (6) discomfort, aches and pains in driving an industrial truck; (7) driver falls with the truck; (8) collisions between industrial trucks and other moving vehicles; (9) industrial truck collides with a stationary object; (10) co-worker falls from the truck, or pinches his hands in a part of the mast; (11) co-worker or driver falls from the truck; (12) items fall from stacks and racks; (13) industrial truck strikes or pins pedestrian, or else collides with another moving vehicle; (14) worker's hand pinched between fork and carriage, or else a fork falls on the worker's hand or foot; (15) the truck tips, and/or the load falls off; (16) the truck strikes or pins a pedestrian, or else collides with a stationary object; (17) a number of different hazardous events infrequently mentioned that had not been initially sought after in the field work; (18) a number of different factors that were mentioned as contributing to more than one kind of hazardous event, but not any one kind in particular. Where a factor was mentioned as contributing to two or more specific kinds of hazardous events, it was listed under each of the appropriate categories.

In light of several considerations, however, it was decided that this analysis by nature of the hazardous event to which the mentioned factor contributed was not the analysis relied upon for the major conclusions of this segment of the study. One such consideration is the rather large number of technically interesting items that per force appeared in the last category. It was felt that several of these items have a great deal of explanatory value that could be too easily overlooked in the context of this sort of analysis. Another consideration was the technical interest afforded by items in the seventeenth category, and the importance of factors mentioned under those headings in explaining several sorts of industrial-truck safety problems from a systems point of view. A third and probably weightiest consideration was the fact that, as the analysis proceded, it became clear that a large number of factors mentioned in connection with one kind of hazardous event by one batch of discussants were also mentioned in connection with other kinds of hazardous events by the same discussants, and by other discussants as well. In light of the pervasive nature of these factors, it appeared that the specifically human factors, including problems stemming from design-deficiencies in the trucks themselves, would come most effectively to light in an analysis that focussed on these cross-category factors. It appeared also that if these cross-category factors were to become the focus of accident-prevention efforts, a greater number of kinds of hazardous events could be affected.

Subsequently, then, the notes from the field observations and conversations were re-analyzed with a view toward disclosing factors that contributed, in the view of our expert discussants, to more than one kind of hazard. This analysis yielded a list of some thirty-eight common cross-category factors that fall into 5 rather natural categories: (A) systems-features of industrial-truck operations in plants, including such matters as worker training, maintenance of the trucks, availability of accessories and attachments, and the age of the trucks in use; (B) behavioral/operational requirements of workers in their tasks, including such matters as backing up, turning, warning others of one's presence, servicing the truck, and blocking wheels of highway trucks and railroad cars; (C) observable characteristics of the task-site, including such matters as crowded, cluttered aisles, heavy concentrations of traffic, and the condition of the driving/walking surface; (D) characteristics of the load, including such matters as poor palletizing, and inherent instability of the load; (E) features of the trucks themselves, including brakes, leaks in hydraulic systems and transmissions, safety devices, emissions from the trucks, anthropometric and ergonomic design features, visibility problems, and rider confusion about controls. Figure 4-8 provides a full list of the thirty-eight factors disclosed in this analysis. Within each of the 5 categories, factors are presented roughly in descending order of combined frequency of appearance in the Workers' Comp. causal data and in the notes of the field conversations.

In the course of analyzing the notes of the field conversations, care was taken to distinguish among factors that have their origin during the course of workers performing their materials-handling tasks, factors that have their origin somewhat before workers begin their material-handling tasks, and factors that have their origins at rather greater spatiotemporal remove from the actual materials-handling tasks. This analytical step was prompted by consideration of the model of hazard management that focusses on the individual worker and the work-team as the primary locus of feedback-and feedforward control of conditions and events that affect the safe and effective accomplishment of the tasks at hand. On this model, the contribution of physical and environmental conditions in the plant and of persons not directly engaged in the tasks at hand is to be examined in terms of the ways in which these other items and persons render easy or difficult the effective feedback-and-feedforward control workers exert in the course of performing their tasks.

For a full discussion of the model of hazard management and of the individual worker and work-team as the primary locus of feedback-and-feedforward control of conditions and events that affect the safe and effective accomplishment of their tasks, see the sections above in Chapter 2 devoted to these matters.

During-the-task factors would include matters like a driver's backing his truck up without first looking behind him, warning others of one's presence, and between-task matters such as reaching into the engine-compartment of the truck to perform a service-adjustment to the motor, adjusting the width of the forks, changing the fuel tank or the battery--in short, most of those items included under the heading of behavioral/operational requirements of workers in their materials-handling tasks. It should be noted, however, that several factors that interact with these during-the-task factors have their origins either just before the workers initiate their material-handling tasks, or in some decision or action or omission that occurred even more remote from the task.

Factors that arise just before the task is begun include decisions about how, when and where the task is to be done, which are made by persons involved in or closely related to the tasks; the category also includes certain conditions that can vary from one forklift trip to the next, viz. the condition of the load in particular. Examples of just-before-the-task decisions that can contribute to hazards would be the decision of a foreman or supervisor to handle large rolls of paper with a standard carriage-and-forks attachment while the clamp-truck is down for repairs, or the decision of an industrial-truck driver to request a co-worker to ride on an out-sized load to stabilize it, or the decision of a driver or co-worker to raise someone to perform an odd job at height on the bare forks or an empty pallet. Problematic conditions of the load include its size, its weight, its center of gravity, and the way it is palletized.

Figure 4-8

Thirty-Eight Common Factors In Forklift Hazards

A. Systems - Features of industrial-truck operations in plants.
   1. Training of workers for those portions of their tasks that involve interaction with industrial trucks.
   2. Production-speed stress.
   3. Availability of tools & atachments & accessories.
   4. Assignment of trucks and drivers to each other.
   5. Maintenance of trucks.
   6. Pay-scales and Job-Prestige Levels.
   7. Age of trucks.

B. Behavioral/Operational Requirements of Workers in their Tasks.
   1. Backing up.
   2. Turning.
   3. Warning others of truck's presence.
   4. Requesting/Giving rides on the truck, load, Bare Forks or Empty Pallet.
   5. Walking and working in the General Area of Lift-Truck Operations.
   6. Communication during shared tasks, or in shared spaces.
   7. Parking the truck.
   8. Blocking wheels on semi-trailers and railroad cars, checking on blocking and bed-surfaces.
   9. Non-required behaviors--Horseplay, showoff driving, jerky driving.
   10. Generally attentive operating.
   11. Servicing the trucks.

C. Observable Characteristics of the Task-Site.
   1. Narrow aisles.
   2. Crowded, cluttered aisles.
   3. Intersections and doors.
   4. Concentrations of traffic.
   5. Condition of the driving surface.
   6. Environmental conditions -- noise, obnoxious odors, toxic gases, dust, lighting.

D. Characteristics of the Load.
   1. Poor palletizing.
   2. Pallets in poor repair.
   3. Load is too heavy.
   4. Load is inherently unstable or blocks vision.

E. Features of the Trucks.

1. Brakes.
2. Steering.
3. Malfunction of clutch, shift linkage, or transmission.
4. Malfunction of speed-and-direction switches.
5. Leaks in hydraulic systems and/or transmissions.
6. Driver vision.
7. Ergonomic design features.
8. Safety devices lacking, inadequate, or malfunction.
9. Emissions from trucks.
10. Driver confusion about controls.

The more remote factors include a wide range of matters that are typically decided upon some weeks or months or years before materials handlers begin the tasks in which the factors can present problems, and typically by managers, purchasing agents, and other persons not directly involved in the materials-handling tasks themselves. This group of factors includes physical features of the workplace and operating procedures, supplies of attachments and accessories for materials-handling by industrial truck, planning for the system of maintenance for the truck, amount and kind of training provided for materials handlers and truck mechanics, and other aspects of overall plant operations design and the design of individual workers' jobs. It should be clear that these factors need not be hazardous in and of themselves; yet, in many cases changes in these factors can help to reduce hazards and accidents that arise later.

During the Task

Factors that arise during the actual performance of materials-handling tasks using powered industrial trucks consist largely of maladaptive behaviors of the workers in response to certain operational and behavioral requirements imposed upon them as a part of the tasks at hand. From the Workers' Comp. causal information and the field-observation notes, it would appear that the most frequently problematic operational requirement for industrial-truck drivers is backing up, and the most frequent maladaptive behavior would be backing the truck without first checking behind for obstructions and/or traffic.

Backing up--
The process of backing up, particularly without looking first, was cited in the Workers' Comp. records and in the field notes as being involved in actual and potential collisions, whether with stationary objects or pedestrians or other moving vehicles, in the load falling off the truck, in the truck tipping, in the truck and driver falling off of the dock, and in discomfort of the driver in operating the truck. The process of backing up, particularly without looking, was mentioned as combining with a great many other factors with the effect that a hazard (as defined above in Chapter 2) is created. In combination with factors like turning, carrying the load too high, narrow and/or crowded aisles, poorly palletized load, unpredictable pedestrian behavior, traffic concentrations, malfunctions of the truck particularly in the brakes, slippery or uneven driving surface, driver confusion about controls particularly the means of actuating service brakes, failure of others to hear or give or heed warnings, noise from truck engines and/or in the plant in general, and workers wearing hearing protection, backing up constitutes an important hazard.

Several items were offered by lift-truck drivers toward explaining why a driver might back his truck up without looking. For one matter, a worker noted that one tends to get a stiff neck from turning around to back up with a sitdown rider truck; even when one does turn around on such a truck, he cannot turn a full 180° from the normal driving position. One must turn to one side or the other, and thus can miss important visual information from his blind spot. One might also fail to turn around to look while backing because he is attending to obstructions or other problematic conditions on one side of the truck or surrounding the load. Another worker explained that it is rather common for a driver to be involved in a task that requires several maneuvers of backing and going forward. The driver may check for traffic and obstructions just prior to the first backing maneuver but not before the second one because he has just checked a few seconds ago.

This researcher also noted that forklift trucks are almost never equipped with any sort of rearview mirror.

Turning--

This operational requirement also appears problematic, and the chief maladaptive behavior here appears to be a driver's going around a corner too fast or failing to stop to check for traffic. The operational requirement of turning tends to be involved in the same kinds of accidents and hazards as backing up, and tends to combine with the same sorts of additional factors to produce these hazards and accidents.

The chief reasons offered by discussants to explain why a driver might turn too fast or fail to stop at an intersection was that he has been instructed to hurry. Also mentioned in this connection were inexperience, unfamiliarity with the area, and overfamiliarity with the area.

The pressure on the driver to hurry is in turn explained by several other matters mentioned by discussants in this connection. Discussants rarely mentioned drivers of industrial trucks being paid on an incentive plan, but they did report that it is fairly common for the work-stations supplied by industrial-truck drivers to be on such a pay-plan. Discussants reported that production workers and drivers of highway trucks rather frequently urge the forklift drivers who supply them with materials to hurry and bring another pallet-load of parts, or hurry and get the trailer unloaded and reloaded. One forklift driver mentioned this production-speed-stress as one of the greatest safety problems of his job.

Less frequently mentioned, but technically interesting, is also a production-speed stress imposed by the plant operations in themselves. Such a stress can arise for a forklift driver when there is a lack of coordination among the work-stations he services. If, for instance, an up-line production process is markedly faster or is producing an item other than what is needed by down-line workstations; the up-line process can quickly swamp the interim in-process storage space allotted forcing the forklift driver to make extra trips to extra length to pick up from the one workstation and still keep pace with the needs of the down-line stations. According to the discussants, the forklift-driver's reaction to this kind of stress is to hurry up, and to omit safety-steps like slowing down for turns, stopping at intersections, lowering the load before trying to turn the truck, and so on.

Establishing and Maintaining Communication--
Establishing and maintaining communication among workers who are operating in the same area, or who are engaging in shared tasks, is a common-sense behavioral requirement of any task in which one is not working entirely alone. Failure to fulfill this requirement can lead to several kinds of very nasty hazards and accidents. Although this factor was not sought after directly in analyzing Workers' Comp. records or in the field observations, it made its appearance in both sources of information, and its importance became quite clear in analyzing information from both sources. Workers' Comp. records show a number of cases in which a pedestrian worker was struck or pinned by an industrial truck while the pedestrian's back was toward the truck; injured pedestrians report that forklift drivers have failed to warn them of the truck's presence; discussants report that pedestrians workers do not always hear or heed the warnings drivers may give.

Workers' Comp. records also show several cases in which a co-worker riding on the load or working at height on bare forks or an empty pallet were injured when the driver moved the mast or the truck unexpectedly. Discussants also mentioned the hazards of a co-worker's hand becoming caught in the clamp or scissors of a push-pull attachment, and the load falling off or else the truck tipping as a driver attempts to evade a pedestrian.

Lack of effective communication among workers sharing the same general area or the same task can combine with and be exacerbated by a list of other factors that is nearly endless. Narrow, crowded aisles, the presence of blind intersections and doors, visibility as a feature of the truck or the truck-load combination, noise in the plant, quiet-operating electric trucks, workers wearing ear protection, warning devices on the truck malfunctioning or simply not existing, concentrations of traffic, the condition of the driving/walking surface, and other factors yet, all can interact with the lack of effective communication among workers sharing the same general space and/or tasks.

As reasons why drivers do not always give effective warnings, discussants offered the following: the noise of constant beeping, or backup-bells or sirens can be quite annoying to the driver and to pedestrian workers who are not part of the traffic; warning lights and horns are sometimes inoperative, due to poor maintenance of these items; some trucks lack horns altogether, and rather few trucks are equipped with warning lights or backup bells or backup sirens. Discussants mentioned that a driver might be unaware of these problems if he has failed to check out his truck before beginning his tasks with it, or if he is inexperienced.

As reasons why warnings given are not always heard or heeded by pedestrians, discussants mentioned that pedestrian workers may be absorbed in their own tasks, e.g. checking goods in or out, fetching help for a jammed production machine or conveyor, or working at their own work station; pedestrians seem to be unaware of technical aspects of industrial trucks like stopping distances and limitations to drivers' vision; pedestrians seem unaware of the potential for serious injury presented by even a small industrial truck.

Two other technically interesting impediments to the establishment and maintenance of effective communication among workers sharing the same general space and/or tasks were brought out by workers as well. One impediment is a consequence of a seniority system in which the most senior workers are not trained or experienced in operations that involve complex sharing of tasks between a lift-truck driver and a pedestrian co-worker. When one member of such a team is absent from work, he may be replaced by a worker with greater seniority in the plant, but less training and experience in the complex shared tasks. Lacking knowledge of when and how to establish effective communication with the other member of the team, the inexperienced worker represents a hazard all on his own.

Another technically interesting impediment involves right-of-way rules. A foundry we visited transports molten metal from the furnaces to the pouring stations in ladles hauled by industrial trucks. In this foundry, the trucks have the right of way when they are loaded with the melt, but not when they are empty. The problem in feedback control of these situations by pedestrian workers consists in the fact that these workers cannot determine when the trucks are carrying melt and when they are empty.

Since the matter of communications was not an issue broached directly by researchers during the observations and conversations, little illumination was gained on the question of why pedestrians do not always annouce their presence to forklift drivers, or why communication is not always maintained among workers engaged in shared tasks.

Blocking the Wheels--
Blocking the wheels of highway trucks and of railroad cars to prevent these vehicles from moving while they are loaded or unloaded by industrial trucks is a task required to be performed by sections (k) and (m) of the OSHA standard for industrial trucks (1910.178). Section (m)(7) also requires that the bed-surfaces of highway trucks, semi-trailers, and railroad cars be checked before driving industrial trucks onto them. Yet these things are not always done, and even when they may have been done, the driver of the industrial truck is not always made aware of conditions. These operational failures can lead to the driver losing control of the truck, the truck falling through the bed of the highway truck or railroad car, the forklift truck falling through the gap between the highway truck or railroad car and the dock, or the highway-truck driver pulling away from the dock with an industrial truck still inside the highway truck.

The failure to block wheels, to check on blocking, to check on the condition of bed-surfaces, and to inform the industrial-truck driver can occur in combination with conditions like too-light dockplates, slippery dock driving surface, and a slippery surface under the semi-trailer to produce accidents in which an industrial-truck driver falls with his truck. It also happens that the dolly-wheels of semi-trailers collapse with an industrial truck inside.

Discussants told us that in their plants, no one checks on these things. In some plants, drivers of highway trucks are assigned the task of blocking the wheels, and in some plants, signs are posted in the loading/unloading area to remind them of this responsibility; but in these same plants, we were told that no one checks up on these matters. We encountered only one plant in which responsibility for checking was clearly assigned. Discussants also mentioned, in several plants, that wheel blocks were simply not available in the plant at all. Discussants mentioned further that unless someone else makes himself responsible for checking the blocking of wheels and the bed-surfaces, the industrial-truck driver must get down off his truck to check--but even this cannot be done when cushion doors are used on the loading dock.

Somewhat before the Task

As mentioned above, factors that arise a rather short time before the task can include two sub-types of factors: (a) decisions of drivers, co-workers, foremen and supervisors about how and when the task is to be done (b) certain conditions, primarily conditions of the load and of the driving surface and of the aisles, that can vary from one forklift-trip to the next, and thus must be adjusted to more or less at a moment's notice.

Requesting/Giving Rides on the Load, Bare Forks, or Empty Pallets-- One such decision, typically made shortly before workers embark on a task, is the decision to have a co-worker ride on the load, the truck, the bare forks, or an empty pallet. This sort of decision can lead to the co-worker falling off the truck, falling off the truck and getting run over by it, catching his hands in part of the lift mechanism, or even being slammed into an overhead obstruction. While such decisions can be carried out without untoward incident, as indicated by the fact discussants said that they did not regard such decisions as very frequent occurrences or terribly serious matters, the decision can be compounded by the failure of the workers involved to establish and maintain effective communication with each other during the task itself (cf. above).

Discussants mentioned that co-workers sometimes "hitch" a ride on the forks of an industrial truck to avoid walking to a "distant" break area or washroom, or to carry fuel to refill a tank on a truck that has run out of fuel far from where the fuel is stored. Discussants mentioned that co-workers are occasionally asked to ride on the back of a truck to act as two-legged counterweight when the load is somewhat above the truck's capacity. Co-workers are asked to ride on the load itself sometimes to help stabilize it when it is much longer than the forks, very wide, or consisting of rather large loose items like scrap lumber. Co-workers are called upon to ride up to height on bare forks or an empty pallet to perform "odd jobs" at height. Most of these odd jobs seem to be unprogrammed events and conditions that come up with little or no notice, (cf. above in Chapter 2 on the subject of variances) such as the need to unjam an overhead conveyor, or fetch down a single item or two from a high shelf, or to begin unloading a railroad car or highway truck in which the load is so messy that unloading in the conventional way by industrial truck cannot begin immediately. Inventory is also taken by this method in some plants.

Discussants proffered several reasons why such decisions might be made: it can be that no appropriate truck or attachment or stacking-container is available to handle the overweight or outsized or "messy" load; loads do shift and settle inside highway trucks and railroad cars during transit; rather few trucks have fuel gauges on the dashboard, so that a driver can easily run out of fuel far from where fuel is stored; no ladder or other device appropriate to working at height is readily available near where it is needed.

Researchers noted that only three of the dozen plants visited possessed any device other than order-picker trucks for working at height: two owned self-propelled lifting-platform vehicles for use by the maintenance department, and one had a working platform equipped with guardrails that could be attached to the forks of an industrial truck. Researchers found it remarkable that these three plants owned only one such device each.

Loads are Overweight, Outsized, Inherently Unstable, or a Block to Driver Vision--
These conditions of the loads that industrial-truck drivers must transport are matters that can change from one trip of the forklift to the next, and must be adjusted to more or less on the spur of the moment. These conditions can lead to the load falling off on a helper or bystander, the truck tipping either forward or to its side, to the helper falling off the truck (see just above), to the helper catching his hands in part of the lift-mechanism. (see above).

The factors that can combine with these conditions of the load are quite varied: the list includes such operational mistakes as carrying the load too high, travelling too fast for conditions, turning too fast, not getting the forks far enough under the load, and swerving to avoid a pedestrian; conditions of the workplace are included as well, such as narrow, cluttered aisles, slippery, or littered or uneven driving surfaces; facets of the truck figure in as well, such as its being equipped with forks that are too short for the load, or with an attachment inappropriate for the load such as standard forks to handle large rolls of paper, or malfunction of the truck's brakes or clutch or transmission or hydraulic system or mast chains, or differences of design between makes of truck that render it possible for a driver to become confused about some aspect of the controls, particularly how to actuate service brakes, or the visual obstruction presented by the lifting attachment, particularly a push-pull attachment.

Implicit in our respondents' discussions of these problematic load conditions was the same reason that they gave to explain why co-workers are asked to ride on the truck or the load--viz. that equipment appropriate and adequate for handling these loads is sometimes (in some plants, discussants seemed to think the equipment is always) unavailable.

Loads are Poorly Palletized--
Poor palletizing of loads is itself a group of factors, for there are several ways in which a load can fail to be palletized properly. When a load consists of items of different sizes and shapes, it can easily happen that there are empty spaces in the stack, with the result that some upper items in the load are not supported. The weight of the load may be concentrated on one part of the pallet; items can be stacked on a pallet so that part of the load overhangs the pallet. The load can consist of slippery items, like cartons coated with oil- or water-resistant substances, or of items like pieces of pottery or castings that cannot be neatly nested into one another. When loads like this are not secured against internal movement, or are not secured to the pallet, and are not handled in special palletizing containers, they can present problems. The hazards to which poorly palletized loads contribute include, obviously enough, the load falling off the truck. But poor palletizing was also cited as contributing to the truck's tipping either forward or to the side, and to part of the load hanging up on nearby objects, as well as items falling from stacks and racks.

As compounding factors, discussants mentioned operational matters like cornering, carrying the load too high, attempting to avoid a pedestrian, physical features of the workplace like narrow aisles and littered or slippery or uneven driving surface, poor lighting in areas where the truck operates and crowded aisles. Truck features include malfunctions of various parts of the truck and design features that contribute to driver discomfort in operating the truck. Differences in design between makes of truck can contribute to driver confusion about the controls. Discussants mentioned also that a pallet that is itself in poor repair with boards missing or broken is an important compounding factor.

Discussants revealed the fact that several aspects of poorly palletized loads can remain hidden from the industrial-truck driver until it is too late. Pallets with boards missing or broken are often hidden underneath loads, and items overhanging the pallet can be obscured by nearby pallet-loads and on a side of the load away from the driver's direct line of vision. This fact would explain in part why such unsafe loads are actually handled.

Discussants left researchers with the distinct feeling that drivers of industrial trucks often find themselves without the necessary time or authority or assistance to correct poor palletizing when they are able to recognize it prior to engaging or carrying the load. Drivers seem to feel that most of the time, they have no choice but to carry such unsafe loads in their unsafe condition. If indeed true, this also would go a long way in explaining why unsafe loads are sometimes transported. There is often nothing left for the driver to do but "grin and bear it", as the saying goes.

Discussants offered some reasons why poorly palletized loads are encountered. One important fact is that goods do shift and settle in highway trucks and railroad cars in transit. Another is that during busy seasons, goods come in and go out of the plant in greater quantities and at a quicker pace than normal. Under such conditions, palletizing procedures tend to deteriorate.

A chance discussion between this researcher and a highway-truck driver (unfortunately not recorded) revealed several other interesting matters: the manual materials handlers typically assigned to load and unload highway trucks and to place objects on pallets are usually low-skill workers who are at the bottom of job-prestige and wage scales in the plant. Manual materials-handler appears to be typically a low-pay, high turnover position for which workers are typically not trained and poorly supervised. This driver reported that in his experience at several plants, the workers who form loads on pallets either do not know how to palletize properly or do not care. They are typically not shown how or why it is important, and their supervisors often do not insist upon good palletizing, and do not allow time or help in re-doing work poorly done. If this is generally the case, as it seems to be, it can explain why poor palletizing occurs, and can also explain why loads can shift and settle in highway trucks during transit.

Littered and/or Slippery Driving Surfaces--
Workers' Compensation records and field conversations show these kinds of conditions to be involved in such unhappy events as drivers losing control of their trucks, trucks tipping over on their sides, pedestrian workers slipping and falling, walkie-truck operators slipping and falling and being struck by the handle of their own trucks, the load falling off, and the steering wheel or handle breaking free of the driver's hands and striking him.

Compounding factors mentioned include such operational requirements as backing up and turning, such operational mistakes as travelling too fast and travelling with forks or load carried too high, or travelling forward with load blocking vision, and such physical features of the workplace as narrow and cluttered aisles, blind intersections and doors, and illumination. Also mentioned was a feature of plant operations-design, viz. concentrations of traffic. Litter on the floors was said to combine with certain design features of the trucks to produce driver discomfort: the lack of springs and shock absorbers in truck suspensions, hard seats, and designs in which the driver is to stand and steer by a lever at his side.

The sources of litter and slop on the floor were said to be the industrial processes themselves that generate debris. It was also mentioned, however, that rain and snow sometimes blow onto the loading dock from outdoors, and that objects stored outdoors and then brought in bring water and mud with them, and on the tires of the industrial trucks. It was also frequently noted that industrial trucks themselves sometimes leak transmission oil and/or hydraulic fluid.

Industrial debris on the driving surfaces was said to be problematic because housecleaning operations were not adequate to remove it before an industrial-truck driver would encounter it. Excess metal from castings, and paper from order lists are not picked up frequently enough, and floor-dry is not always spread to soak up water or oil soon enough.

Leaks from the trucks were said to stem from problems in maintaining the trucks, primarily from the difficulty in obtaining parts like oil seals for the old trucks in use in many of the plants we visited.

Factors of More Remote Origin

It will be noted in the foregoing discussions of during-the-task factors and factors that arise somewhat before the tasks begin, that many of the compounding factors and many of the reasons why the factors discussed arise at all can be traced to further factors that tend to arise days and weeks and months and sometimes years before materials handlers begin their concrete tasks in which the factors contribute to hazards. These further factors are typically the results of decisions and actions and omissions of persons themselves rather removed from the actual tasks of handling materials with industrial trucks: managers, purchasing agents, industrial planners, and designers of industrial trucks. Discussants mentioned several such more remote factors as contributing in important ways to hazards. Some of these factors are relatively fixed features of the workplace such as aisle width, storage facilities and practices that affect aisle width, and traffic engineering in the plant. Other factors of more remote origin that were mentioned as contributing to hazards fell into a group that could be called systems-features of industrial-truck operations. This group of factors includes such matters as the system of maintenance for the trucks, the way in which trucks are selected for use in the plant and the way in which trucks and drivers are assigned to each other, the training provided for industrial-truck drivers and manual materials-handlers and truck mechanics, and the age of the trucks in use in the plant.

Crowded, Cluttered Aisles--
Aisles crowded and cluttered by interim and in-process storage are shown to contribute to five different kinds of frequent and severe accidents: collisions of industrial trucks with pedestrians, with other moving vehicles, and with stationary objects, often knocking them onto someone else; the load falling off the truck on a helper or bystander; driver pins himself against a stationary object.

Crowded, cluttered aisles were found to combine with quite a number of other factors to produce these kinds of accidents: behavioral miscues like unpredictable pedestrian behaviors, drivers travelling too fast, drivers travelling forward with the load blocking their vision, drivers not looking in the direction of travel, and drivers failing to sound their horns; also mentioned as compounding factors were certain physical features of the plant, especially the condition of the driving surface, intersections and doors, aisles that are too narrow to begin with, and noise in the plant that prompts workers to wear hearing-protective devices; truck malfunctions of various sorts and limitations to drivers' visibility were said to compound the problems presented by cluttered aisles.

Goods stacked in aisles, at the ends of storage racks, and in areas that might otherwise be completely open create their own set of blind intersections, and when a driver is inexperienced, or under pressure to hurry to supply work stations or complete loading/unloading tasks, he may find the aisles difficult to cope with adequately.

Crowding and cluttering of aisles by goods stacked and stored there arise for different reasons in different plants, but most of these reasons can be traced to one aspect or another of the design of the industrial operations of the plant. In one plant we visited, in-process storage consisted largely of the sides of aisles. Partly-finished items were stored there between work-stations in stackable containers. Researchers noted that the items were neatly stacked, and were piled only one layer deep along side the aisle-way, but drivers of industrial trucks in the plant mentioned that with these storage practices, the aisles were not wide enough for two 2-1/2 ton sitdown rider trucks to pass going opposite directions. This in-process storage was made necessary in part by the fact that the general storage areas were filled with raw materials and supplies and objects that would not need to be moved again only a few hours later. There was no other available space in the plant for other kinds of storage, and the work-stations to which the in-process stored goods were generally not very distant from the work-stations from which the partly-finished goods came.

In one warehouse we visited, goods were unloaded into a staging area by drivers of one kind of industrial truck, were transported to the storage-rack and set down in the aisle in front of the appropriate section of shelves by drivers of another kind of truck, and placed in the shelves when this was possible by a third truck of a different kind. By admission of the warehouse's managers, this facility was drastically overstocked largely because the managers' superiors did not allow acquisition of any more storage space or remodeling of present facilities for greater efficiency, and did not instruct the company's buyers to slow down in acquiring new goods when warehouse space was exhausted. Workers in this plant reported that the overstocking lead to "temporary" storage in the staging areas at the receiving dock becoming "permanent", to stacking goods at the ends of storage racks, to stacking goods so that fire exits and fire extinguishers were blocked, and to very difficult pathways through the aisles between storage racks. To make things worse, workers said that rejected and damaged goods were not picked up often enough by the firm's suppliers, creating crowding in the shipping-dock area.

In a third plant, aisle storage was made necessary by the seasonal nature of the business. Even though the building itself was only eight years old at the time of our visit, workers reported to us that the amount of goods coming in to the plant in preparation for the Christmas busy season outstripped the capacity of the storage racks, and so goods would be stacked at the ends of storage racks (i.e. along side the cross-aisle), and in impromptu rows of stacks in areas that would otherwise be empty. This latter practice was mentioned as compounding the problem already presented by receiving clerks popping out of nowhere: in the busy season, drivers noted that there is more "nowhere" out of which pedestrian workers can pop.

Maintenance and Age of the Trucks--
Trucks that are not properly maintained are obviously more prone to malfunction than trucks in good condition; truck malfunctions can contribute to accidents of nearly every conceivable kind. The truck-elements that our discussants mentioned most frequently as being prone to malfunction as a result of inadequate maintenance are discussed below in a section on truck malfunctions. Our field conversations brought to light a great many important ways in which the maintenance-system for trucks can itself break down. Poor performance on the part of the maintenance department can infect nearly every aspect of truck operations with problems, and for that reason the subject is broached here.

Many of the reasons for the occurrence of poorly maintained trucks stem in the first instance from the drivers themselves. Drivers do not always give their trucks a thorough checkout before starting their tasks with the trucks; drivers do not always bring in trucks with defects they recognize when the problem arises, but often wait for the end of the shift or longer; drivers sometimes defeat certain controls on the trucks, e.g. the deadman braking feature of walkie trucks. This feature is defeated by attaching a length of tape between the handle of the walkie and the main body of the truck, so that when the operator lets go of the handle it will not fall all the way to a horizontal position that would ordinarily stop the truck. Drivers were said to abuse the trucks knowingly by, e.g. knowingly overloading them.

It should be noted, however, that these failures on the part of drivers of the industrial trucks can themselves be explained by further facts also mentioned by our discussants. Drivers said, and some mechanics corroborated this, that they could not always be sure to get their maintenance requests attended to in timely fashion. Drivers in three plants mentioned that the maintenance department seems to be always "booked up" with repair requests that had come in earlier. Drivers also mentioned that maintenance departments do not always have the parts needed to fix a truck properly. They noted that particularly with old trucks, the parts are likely to be hard to find and long in arriving at the plant. In the meantime the drivers must continue to use defective trucks. In a fourth plant, drivers and mechanics reported that the truck maintenance crew was so understaffed and poorly equipped that almost all maintenance effort had to be devoted to trucks that had broken down to the point of not running at all. In a fifth plant, workers noted that under the previous maintenance supervisor, work-priorities were set so that problems he (though not necessarily the worker confronted by them) thought unimportant were not attended to at all; in the same plant, maintenance requests had to receive approval from the driver's foreman, who might well throw the request in the trashbasket for no stated reason at all. Under such circumstances, drivers felt they had little reason to be assiduous in discovering and reporting defects.

In particular, the defeating of the deadman-brake feature of walkie trucks in the plant where the practice was noted, was said to be prompted in part by the fact that this feature malfunctioned frequently and was not adequately maintained.

Other failures and poor practices on the part of drivers are explicable by the demands of the drivers' own jobs. It takes much longer, and gives rise to possible confusion and routing mistakes, to break down a large order into two parts and transport the parts separately, particularly when there are no empty pallets handy and not enough order-tags for that purpose, and the load would be only a little over the truck's capacity. A driver may find it an annoyance to interrupt the flow of his tasks to get a defect attended to immediately, particularly when he is being pressured to hurry up by the production workers or highway-truck drivers he services. We noted that in four plants we visited, these other workers were on a piecework or incentive pay-system, even though the industrial-truck drivers themselves were not. This pressure on drivers to hurry (production speed-stress) was noted by our discussants as a cause of drivers' omitting several different kinds of safety steps.

We noted also that at more than half of the plants we visited, drivers and trucks were not assigned to each other on a regular basis. Certain trucks would be assigned to a given operation, and certain drivers would be regularly assigned to that same operation on a regular basis, but in the plants, the trucks and drivers were not assigned to each other on a regular basis. Although drivers did develop preferences about trucks, drivers in these plants could not point to a given truck and say 'that's <u>my</u> truck'. In these plants, drivers were to use whatever truck was available and running. Discussants noted that the lack of identification of any given truck as one's own can prompt drivers to be lackadaisical in detecting and reporting maintenance problems. This comment seems to be borne out by the fact that in all but one plant where this arrangement was in effect, there seemed to be important problems with the maintenance of the trucks, according to our discussants.

Other aspects of operations-design in the plant were noted by our discussants as affecting truck maintenance adversely. Drivers, who may feel themselves pressured to return quickly to their tasks, also impose production-speed stress directly on mechanics. Some discussants noted that mechanics are not always well trained (see also below under Training), and workers and mechanics for nearly half of the plants said that truck maintenance crews were drastically understaffed and poorly equipped with items like hoists and service lifts. Mechanics at one plant reported that their hoist could not be made to function properly, and the service manuals for two of the makes of trucks used there were poorly writen, poorly illustrated, and omitted certain crucial information. (The two models of truck in question are no longer being manufactured.)

In another plant, truck maintenance is performed by a separate contracting firm at three-week intervals. This plant operates its trucks 24 hours per day 5-1/2 days per week. Drivers felt maintenance was done too seldom, particularly since jobs like brake adjustements could not be done in the plant between visits of the maintenance firm.

Researchers noted also that only one of the twelve plants we visited showed any evidence of having a system of regularly-scheduled preventive maintenance. In all other plants, drivers were relied upon to detect matters needing correction and report them. The superiority of the former kind of system is indicated by the fact that, at the plant where the system is in effect workers reported only one kind of important truck-maintenance problem that they did not feel was as yet adequately under control. At all the other plants, there were said to be several.

Discussants also mentioned the age of the trucks at their plants to be a matter that adversely affects both truck operations and maintenance. Researchers found that this concern is not at all misplaced. Actual ages of the trucks we observed are given above under Methods and Preliminary Findings in the Field.

Conversations with manufacturers revealed that truck-makers tend to consider the useful life of the "average" industrial truck to be eight to ten years. If they are right, and if the plants we visited are a representative sample, then most of the industrial trucks actually in daily use in industrial plants are too old to be useful.

Our discussants said that old trucks are more prone to malfunction than newer trucks due to simple fatigue of parts, even if they are maintained "according to the book". They also said that important parts for these old trucks are often quite difficult to come by, and tend to take a long time to arrive even after they are found. In the meantime, the defective truck must continue to be used, in a great many cases. Problems in availability of parts seem worst in relation to oil seals for transmissions and components for hydraulic systems.

Training of Drivers, Pedestrians, Mechanics Palletizers--
It is obvious that the lack of training or inadequate training of workers involved with industrial truck operations can contribute to nearly every kind of accident and hazard imaginable. Our discussants mentioned several kinds of incidents in particular: (a) a driver pins himself against a wall with an electric standup rider truck because he does not know how to apply the brakes; (b) an untrained driver tries to drive through a doorway with the mast raised and knocks three rows of bricks out; (c) a runaway truck nearly hits several pedestrians because no one in the vicinity knew how to brake it; (d) an untrained or inexperienced pedestrian helper in a slip-truck operation can easily have his hand caught in the clamp of the push-pull attachment or be run over by the slip-truck because he does not know how and where to place himself, or how to work with the driver of the slip-truck. Discussants mentioned also that lack of training and/or experience can contribute to a driver's becoming confused by the differences in how to apply service brakes from one make of truck to the next. They said too that poorly trained mechanics can contribute to hazards in the operation of trucks. A chance conversation with a driver of a highway truck revealed that the manual materials handlers who palletize goods and load highway trucks by hand are rarely trained at all, which in part can explain some degree of poor palletizing, and some degree of the shifting and settling of goods in highway trucks and railroad cars during transit. Drivers of industrial trucks mentioned that pedestrian workers in general seem to lack certain important bits of information about the room that industrial trucks require for maneuvering, trucks' stopping distances, and the limitations to drivers' vision. This lack of knowledge, they seemed to think, would in part explain why pedestrian workers do some of the unpredictable things they do, for instance stepping out into an aisle in front of an industrial truck, or failing to announce their presence in an area when the truck driver's back is toward the pedestrian.

Some noteworthy items appeared when we looked at the notes on what discussants said about the training they themselves had for their tasks that involve industrial trucks. Although the vast majority of the drivers we talked with said that they had had some sort of training for their job of driving industrial trucks, the amount and kind of training they had received varied greatly. Forty-four percent of them said they had received an introduction to the truck's controls from a supervisor or experienced worker. In two plants, drivers said they had received this kind of training, and had undergone periods in which they were assigned easy tasks in low-traffic areas at low-traffic times under rather close supervision before they were fully certified as drivers.

The specific statistics we developed concerning training are given above in Methods and Preliminary Findings in the Field.

A further remark seems in order at this point. It appears from indirect comments from drivers of indusitral trucks that such formal training programs as are administered are not designed around and do not include a large component devoted to hazards arising from the specific kinds of jobs the trainees will encounter in the plant. Researchers did not make a point of reviewing the content of the training received by drivers in the plants we visited, but such reviewing as was possible showed only a moderate connection between hazards mentioned by workers in the plant and matters covered in the training materials; those matters tended to be covered in a general, but not plant-specific manner. Those drivers who proffered evaluative comments about their formal training said the programs were adequate in most respects, but did not seem to feel that the programs were "right on" for purposes of driving in that particular plant. It turned out also that these same drivers were themselves highly experienced men who seemed to feel that they themselves were not seriously threatened by the hazards they mentioned. It would appear that the formal training that tends to be offered to drivers is adequate for those who need it least. It is not clear that the same can be said for the utter neophyte driver.

Problematic Features of the Trucks Themselves

Discussants made a great many comments regarding inadequacies of the trucks operated in their plants. Upon examination of these comments, however, it appeared that the vast majority of them were concerned with malfunctions of various elements of the trucks that were traceable first and foremost to inadequate maintenance of the trucks, and in some few instances to poor quality-control at the truck-manufacturer's plant. Comments implicating hazardous design-features of the trucks were much fewer, and most of these fall into the realm of driver comfort. This fact would appear to say much about where efforts should be concentrated in the attempt to prevent industrial-truck accidents. The matter will be taken up at some length below.

Truck Malfunctions--

Workers' Compensation records show malfunctions of trucks to be involved in pedestrians being run over or pinned by industrial trucks, loads falling on pedestrians, the carriage falling on a helper, a co-worker falling from an elevated platform, pedestrian workers slipping in oil leaked from the trucks, collisions of trucks with stationary objects, and collisions of trucks with other moving vehicles. A noteworthy hazard mentioned by discussants was walkie-trucks running down their own operators.

The specific malfunctioning components mentioned by our discussants included the following, in descending order of frequency of mention: brakes, hydraulic systems for lifting and tilting loads, clutches and transmissions and shift linkages, warning devices like lights and horns, and speed-and-direction switches on electric trucks. As noted above, workers traced these malfunctions to inadequate maintenance of these components, and only very rarely to inadequacy of design of the trucks. Where drivers and mechanics did mention design inadequacy in connection with these malfunctions, the mention was either tentative, indicating the worker was not certain in his own mind about the involvement of poor design, or else it was made in reference to a truck that was clearly old and felt by the worker to be obsolete. Most frequently, the worker went on to note that he had encountered newer designs that were much better.

Design Weaknesses Related to Malfunctions--
Although comparatively few in number, mentions of weakness in design possibly responsible for truck malfunctions were sometimes interesting and insightful. Among the least conclusive were mentions of inadequate design of brakes. One driver said that the strictly mechanical braking system on his truck was long since made obsolete by the incorporation of hydraulic braking systems on industrial trucks (his own truck was clearly ancient). Another driver, who worked in a plant in which near-capacity loads were carried continuously 24 hours a day 5-1/2 days per week, said he felt the brakes of the trucks his firm used did not seem to be designed with such use in mind - they needed adjustment every week to two weeks, which he felt to be too frequent. He was the only worker who brought this matter up.

Of somewhat greater interest are the malfunctions of speed-and-direction switches on electric trucks. Drivers and mechanics noted that the mechanically-engaged contact points of the switches on the trucks they used were subject to wear, and could even weld themselves shut under prolonged heavy use, particularly when the maintenance of these items is not adequate. But they noted that this problem is greatly reduced by the fully-electronic switches with no or few moving parts that are incorporated into some of the newest trucks. These kinds of switches wear better and need less maintenance, they said.

Malfunctions in the hydraulic system and the trouble mechanics are said to have chronically in getting these systems to work properly and without leaking would seem intuitively to be traceable to poor design of such systems. Drivers and mechanics mentioned these malfunctions in connection with nearly every make of truck we observed, and engineers we talked with freely said that every make has trouble with the hydraulic system. Both workers and engineers refrained from going so far as to impugn the design of these systems, however, and seemed to feel that hydraulic-system problems were just one of those inevitable unpleasant facts of life with industrial trucks.

Inadequate Safety-Devices--
A large portion of the complaints about inadequate safety devices were matters not clearly related to the drawing-board or manufacturers'-engineer level of design of industrial trucks. Instead, they seem to be matters concerning the way trucks are equipped. Only a very few of the trucks we observed were equipped with warning lights; steady-beam warning lights were mentioned as less effective than rotating, lighthouse-type beams of light; horns were mentioned as being not loud enough; load backrest extensions were mentioned as being too low: a canopy was said to be too short to cover the driver's lower extremities when he was seated properly, and to have openings large enough to allow part of his usual loads to fall through and strike him. Workers admitted that most of these problems could probably be cured by bolting on devices available from the manufacturer or from other supply firms, or by fashioning a rather simple device in the plant's own shops. But it can be sensibly argued that a manager or purchasing agent designs the trucks for his plant in a secondary way when he gives the dealer the specifications for the trucks that are needed, and selects the variable features that would be needed in his plant, and calls for modifications to the truck in the respects just mentioned - or fails to do some or all of the foregoing. These matters are discussed here for just these latter kinds of reasons (cf. also above, Chapter 2).

Visibility--
Visibility as design-feature of industrial trucks was very rarely mentioned by our discussants. In one instance, the plant engineer pointed out to this researcher some old trucks (still in constant daily use in the plant) on which the mast was clearly a block to driver vision, with very narrow spaces left between the main lift cylinder and piston and the outer uprights, and hydraulic lines running through the length of one of these spaces (cf. Plate 4-9a; a different truck, but the feature is roughly the same). It is noteworthy that the drivers of these same trucks did not mention this feature as a problem they felt important. On one newer truck, the driver pointed out the presence of the spool for the hydraulic lines on the right front upright of the overhead canopy, and the offset of the driver's seat to the left of the truck as making it difficult to see pedestrians and other moving objects coming from the right. A third driver mentioned the push-pull attachment, and the fact that, unlike pallets, loads placed on slip-sheets cannot be seen through, as notable blocks to driver vision. Rearward visibility was obscured on a group of different trucks by mounting the LPG tank upright (see Plate 4-9b) in response to an engine-overheat problem.

Human-Factors Design Weaknesses--
Complaints in this area concerned mainly considerations of driver comfort, but some other interesting matters were broached by our

FIGURE 4-9 VISIBILITY FROM THE DRIVER'S SEAT

PLATE 4-9B (BELOW)
VISION REARWARD

PLATE 4-9A (ABOVE) VISION FORWARD

discussants as well. Let us turn to some of these first.

One driver mentioned that having the gearshift lever and separate controls for lift and tilt all on the same side of the steering wheel made too many items to be controlled by one hand, leading to possible confusion and to grabbing the wrong lever. He said he appreciated the design of another truck he sometimes used on which forward and reverse are controlled by foot pedals. Two drivers said they appreciated designs in which lift and tilt are integrated into a single lever-control. They said this design could allow simultaneous lifting and tilting, thereby speeding up operations.

As an aside, let us note also that drivers pointed out that confusion about controls is contributed to also by lack of durable markings of the controls. They pointed out that controls are not always marked at all (this was true of the oldest trucks, though not of the newer ones), and that markings tend to wear off rather early in the truck's useful life.

Three drivers mentioned that confusion is possible about how to apply service brakes on standup rider trucks. This was mentioned in three different plants in which drivers were called upon to operate two or more different makes of standup rider trucks, often in the same day. They pointed out that on some makes, service brakes are applied by pressing down on a single pedal on the right of the driver's platform; other makes require a pedal on the left to be pushed down while standing on a "deadman" type of pedal on the right; on other makes yet, brakes are applied by raising one or the other foot from a deadman pedal or button. The latter design is typical in order-picker trucks (cf. Figure 4-10). Drivers mentioned that these make-to-make design differences can be very confusing for an inexperienced driver, and one experienced driver felt this possible confusion to be the main hazard of his particular job. In light of these matters, it would seem to behoove managers to attend to the relationship between truck design and job-design in their plants.

This researcher observes an inherent problem in all designs of foot-actuated brakes for standup rider trucks: regardless of whether brakes are applied by lifting the foot from a pedal or by pushing down on one, the driver is necessarily somewhat off balance when he applies the brakes. Unfortunately, it is not immediately obvious how this condition could be alleviated without adding to possible confusions concerning hand controls.

Two drivers and a mechanic noted a further interesting item related to the brakes of standup rider trucks. They noted that occasionally, accidents occur with standup rider trucks that have brakes actuated by lifting the foot from a pedal. In such cases, the driver sometimes claims brake failure to be the cause, when further investigation shows no defect. Our discussants said such incidents can sometimes be explained by the driver's inadvertently

FIGURE 4-10 THREE DIFFERENT MAKES, THREE DIFFERENT BRAKING SYSTEMS, ONE PLANT

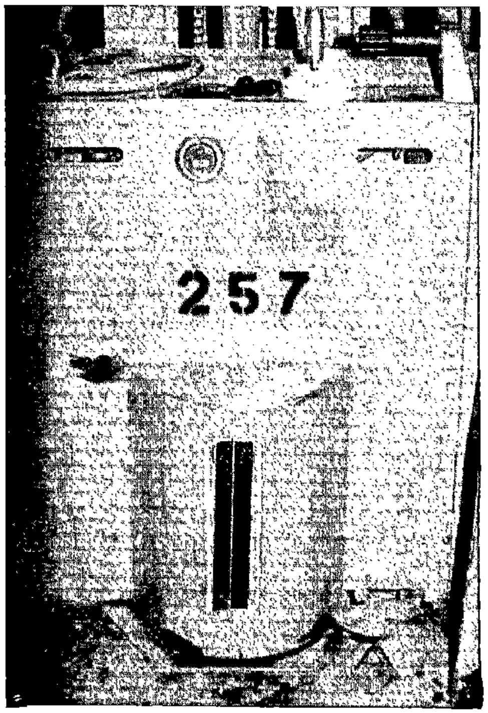
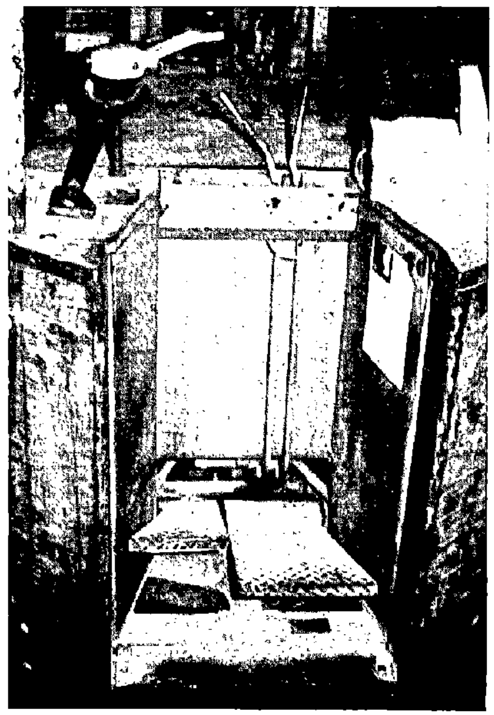


Plate 4-10A (Above)
By Pressing Up With
Right Foot

Plate 4-10B (Below)
By Pressing Up With
Left Foot



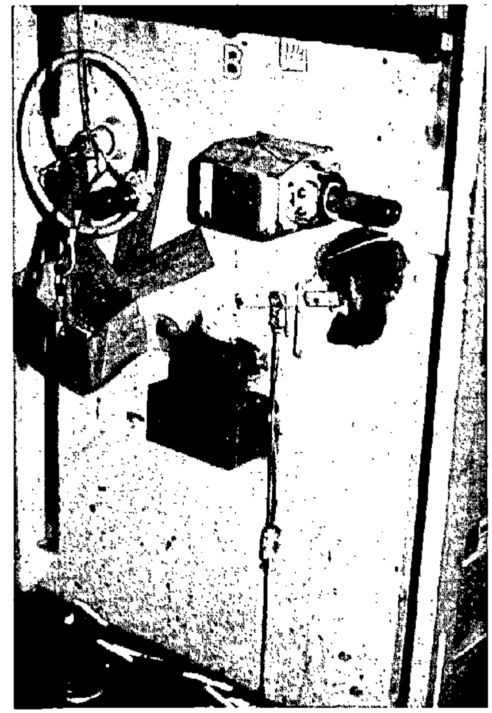


PLATE 4-10C (ABOVE)
BY LIFTING UP
WHICHEVER FOOT

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having both feet on the braking pedal or button. Lifting only one would of course accomplish nothing.

An ergonomic design weakness related to driver comfort also implicates standup rider trucks. Drivers of such devices said that their driving compartments are quite often too confining, even on the roomiest of models. There is often so little foot room that drivers with large feet said that their heels overhang the rear of their platform when they are otherwise comfortable. When drivers of such trucks are called upon to operate them for long periods without a break, they note that their feet and legs begin to become painful, and that in order to shift positions, they must dangle a leg and/or foot, and/or upper extremity out the back of the truck or over its side (cf. Plate 4-11a).

This problem of cramped driver compartments was also noted with respect to some models of sitdown rider trucks (none of which is produced any longer), and can explain why drivers sometimes dangle extremities outside the running lines of the truck, which sometimes leads to their being pinned between the truck and some inconvenient stationary object (cf. Plate 4-11b).

It was noted that seats on sitdown rider trucks are often very hard and lack thigh-support and lower-back support. Drivers said that when they are called upon to drive these (usually old) trucks, they get pains in the derriere and back for their efforts (cf. Plate 4-12).

Drivers noted also that some (usually old) trucks lack power-assisted steering, which causes them to make additional effort in steering and sometimes gives rise to pains in the chest, shoulders and upper arms.

Two drivers pointed out that one is often called upon to drive an industrial truck backward when the load blocks forward vision. On a sitdown rider truck, one must turn his body to do this, and thereby assume an uncomfortable position. Looking where one is going while backing with a sitdown rider truck, they said, is literally a pain in the neck. The stiff neck developed while looking in the direction of travel during backing with a sitdown truck can partially explain why drivers might back up without looking first. It's just a pain in the neck.

Two drivers said that the lack of springs and shock absorbers in the suspension systems of indoor-type industrial trucks, combined with dips and cracks and potholes and debris in the floor as well as highway trucks and railroad cars being lower or higher than the loading dock (due in one case to the dock sinking into the ground at its ends), jolts the internal organs of a driver. These drivers admitted that severe injury would be difficult to prove in this connection, but they said that the discomfort is definitely worthy of attention.

FIGURE 4-11 CRAMPED QUARTERS FOR OPERATORS

PLATE 4-11A (BELOW)
A STANDUP RIDER-CONTROLLED TRUCK

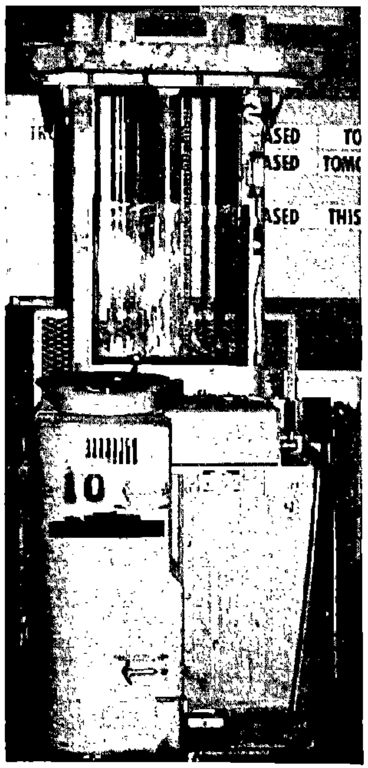

PLATE 4-11B (ABOVE)
A SITDOWN RIDER-CONTROLLED TRUCK

PLATE 4-11C (BELOW)
AN ORDER-PICKER TRUCK WITH 6'6" DRIVER

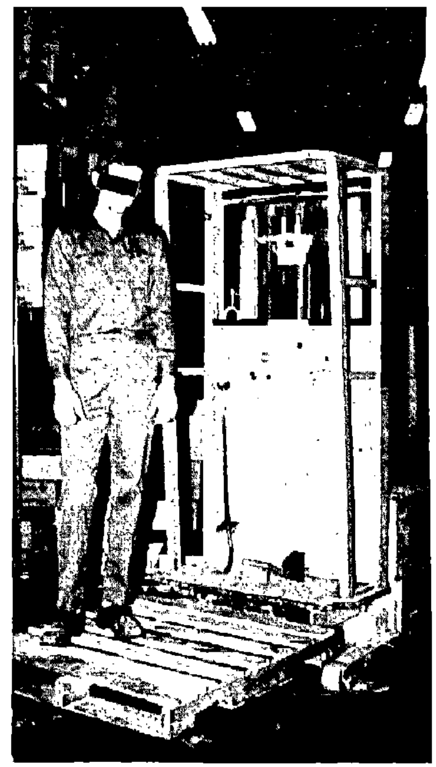

FIGURE 4-12 POORLY-CONTOURED SEATS, THIN PADDING

PLATE 4-12A (LEFT)

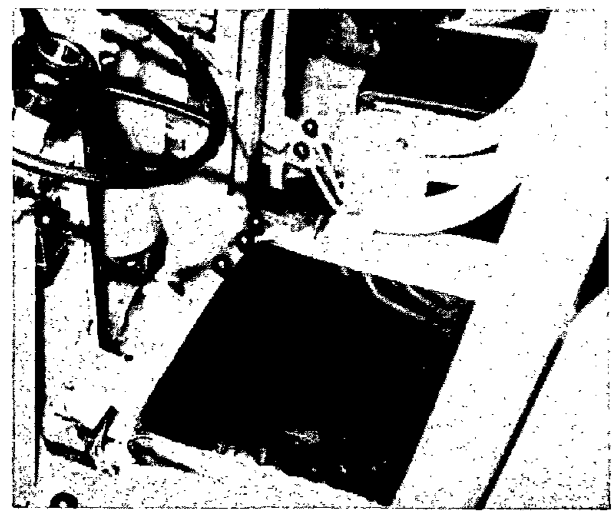

PLATE 4-12B (RIGHT)

Four drivers mentioned that they felt their trucks' engines were noisy, and three mentioned that their seats, located near the engine compartments, did not disperse heat well and so were uncomfortably warm. These complaints, too, involved old trucks.

It bears repeating here that most of the complaints about design inadequacies, including human-factors design weaknesses, were made about trucks five or more years old. Workers noted that with respect to almost all of the complaints they had, newer designs that they had encountered were vast improvements. They said too that the newer trucks they encountered were nearly all much smoother to operate and demanded far less physical effort.

THE FACTORS AND THE SAFETY STANDARDS

The ANSI and OSHA Standards related to Industrial Trucks, viz. B.56.1 1969, B.56.1 1975, and 1910.178, 1910.176, 1910.22, were not a subject of direct investigation for this study. However, as the analysis of the Workers' Compensation data and the field-information disclosed factors that commonly contribute to hazards in lift-truck operations, these standards were searched for clauses closely related to the factor in question. The Appendix to this chapter shows the results of these searches, and lists the number of times the clause was cited in 1975 by OSHA inspectors nationwide.

By way of general summary, it seems fair to say that there are clauses of the ANSI and OSHA Standards related to most of the 38 common factors in such a way that full compliance with the various clauses could conceivably prevent a sizable number of accidents. It seems fair to say, too, that clauses related to important common factors are being cited rather frequently by OSHA inspectors. There are some clauses, however, that relate to important common factors but are not being cited very frequently by inspectors. These clauses are ones that would appear to call for a judgment on the part of the inspector about whether the load being handled is safe, the speed while turning is low enough, the stopping distances allowed are great enough, and some other similar matters. It is not immediately clear from the data available for the present study why these clauses are not cited frequently; it seems a matter appropriate for further study, and will be addressed in the subsequent section of this chapter on topics for further study. It will be argued later in this section that other factors not addressed by the standards, as well as certain aspects of truck design, are not matters about which legislation would appear to be appropriate.

On the basis of the findings presented in the Appendix to this chapter, it would appear that there are few, if any, glaring mistakes or omissions in the OSHA and ANSI standards that could be said to be responsible for significant numbers of severe forklift accidents. Our investigations do indicate some areas in which the standards could be improved, however. There are a few clauses that appear poorly worded, a few that appear incomplete as they stand, and some clauses concerning truck design about which disagreement can be voiced. It will be noted, however, that most of the changes suggested in subsequent paragraphs would be accomplished without great technical-engineering difficulty.

Poorly Worded Clauses

The chief object for potential complaint on this score would be clause (n)(15) of OSHA 1910.178. This clause provides that, while negotiating turns, speed shall be reduced by means of turning the hand steering wheel in a smooth, sweeping motion at a moderate, even rate. As written, the clause would appear to require that all trucks be steered by a hand-wheel; this arrangement is inappropriate for standup rider-controlled trucks, since one-hand steering is needed for almost all of these trucks, and the arrangement is nearly impossible for walkie-trucks. As written, the standard would also appear to require that speed be reduced during the turn and by some means other than "easing off" on the speed control or applying the service brakes. It is questionable whether the procedure apparently required by this clause should even be permitted. Ideally, one would reduce speed, either by "easing off on" the speed control or by applying the service brakes, before initiating the turn. A few word changes could communicate better what one hopes is the intent of the clause, viz. that turns be accomplished smoothly and not too fast.

An object of somewhat less concern is clause (k)(4) of OSHA 1910.178. It appears to be redundant. This clause requires that positive protection be provided to prevent railroad cars from being moved while dockboards or bride plates are in position. Clause (k)(2) requires that wheel stops or other recognized positive protection be provided to prevent railroad cars from moving during loading or unloading operations. If the two clauses are intended to regulate different hazardous situations, some wording changes would seem in order to make that point clear. However, if the same situation is envisioned in both clauses, it would seem that (k)(4) could be deleted, since (k)(2) suggests a concrete way to prevent movement of the cars.

Clause (m)(12) is a matter of rather greater concern, however. This clause deals with trucks equipped with controls elevatable with the carriage or forks. The description as given in the standard would fit only order-picker trucks and certain other, even more highly-specialized, trucks. Our investigations show, however, that order-picker trucks are certainly not the only kinds, and perhaps not even the main kinds, of means used for elevating personnel on industrial trucks. Platforms attachable to and detachable from the forks of an ordinary forklift truck are in some use: these platforms rarely provide for any controls at all to be elevatable with the carriage. It is not clear from the clause as written whether it is intended to apply to this means of lifting personnel or not. If application to detachable platforms is intended, some wording changes seem in order to make this point clearer.

Omissions in the Clauses

If clause (m)(12) is not intended to apply to removable platforms for lifting personnel on industrial trucks, then it does not explicitly include them. Since such platforms are in use, and it would appear that their use is increasing, it would be appropriate to include the provisions of ANSI B.56.1 1975 para. 427 that addresses directly matters of elevating personnel with industrial trucks. This segment of the ANSI standard could be incorporated by transcription or by explicit reference. In view of the rather infamous practice of elevating personnel on bare forks or an empty pallet (see above, in the section on Somewhat-before-the-Task factors, this chapter), it would seem in order to add a sub-clause requiring the use of some approved device for lifting personnel with an industrial truck anytime this is done. In light of our observation that plants tend to own rather few such appropriate safe devices, and tend to keep them at some distance from points at which they are needed, it would seem appropriate to require employers to demonstrate adequate numbers of such devices in good repair near where they are needed. What is adequate and appropriate will of course differ from plant to plant.

Clause (k) of 1910.178 on the blocking of wheels of highway trucks and railroad cars seems to lack an important provision. Our investigations indicate that the primary reason why the wheels of highway trucks and railroad cars tend to go unblocked more often than blocked is that the plant does not own enough of these devices, or that they are not always available near where they are needed. Accordingly, it would seem in order to require employers to demonstrate the presence of adequate numbers of wheel blocks in good repair near where they are needed. Here again, what is adequate will vary from one plant to the next. Also, some allowance should be made for the newer-design semi-trailers on which the trailer's air-brakes are automatically set when the tractor is detached.

As another part of the concern for forklift-safety in loading and unloading operations, we note that in many plants, there is no regular system for checking on the blocking of wheels and the condition of bed-surfaces and for reporting on such matters to the industrial-truck drivers concerned. It would seem appropriate to require employers to demonstrate existence of an effective system for checking wheel-blocking and bed-surface conditions and informing the industrial-truck drivers concerned before they initiate their loading/unloading tasks. Concrete details of how such a system might work can easily be left open, so as to accomodate the individual needs and work-designs of individual plants.

Clause (q)(1) provides that repair of industrial trucks shall be performed only by authorized personnel. It does not provide that the personnel regularly assigned to repair and maintain powered industrial trucks must have had training specifically for repairing powered industrial trucks. Some mechanics told us that their own lack of training was a factor contributing to hazards; we have noted that most mechanics are not trained specifically for repairing industrial trucks; it is obvious that there are important differences between the engineering principles on which industrial trucks are designed and those of automobiles, which some mechanics have been trained to repair. This is particularly so in the case of electric-powered trucks, and the use of these trucks seems likely to increase as the price of petroleum-based fuels increases. The mechanics we talked with seemed to feel, however, that experience in repairing industrial trucks can largely supplant specific training. Thus it would seem in order that the clause require mechanics to be trained or experienced in repairing the trucks.

Clause (o) provides that only stable and safely-arranged loads shall be handled. It provides, in effect, that over-capacity loads shall be adjusted, and that care shall be exercized when handling loads with attachments. Since poorly palletized loads, and loads that are inherently difficult to handle with standard fork-and-carriage attachments, are shown in our investigations to be as much a problem as overweight and too-high loads, it would seem proper to require that loads be handled only with the appropriate device. The appropriate device can be of course many things: a bigger truck, an attachment of suitable size and capacity such as fork extensions or a roll-clamp or barrel-clamp or carton clamp or push-pull attachment, a special stackable palletizing container, or a device that secures the load directly to the pallet or skid used.

Our investigations suggest that one of the major reasons why appropriate devices are not always used is that they are not readily available when and where needed. Hence it seems fitting to require that employers demonstrate existence in the plant of an effective system to ensure the following: adequate numbers and kinds of devices in the plant near where they are needed; all the devices including pallets and skids are maintained in good repair; the use of the devices whenever needed.

And in light of the importance our study found in palletizing loads, it would not seem misdirected to require that employers demonstrate existence in the plant of an effective system to ensure that loads that are not safely arranged are re-arranged and properly secured against internal movement prior to handling with industrial trucks.

We note also that neither 1910.178 nor 1910.176 requires that those responsible for forming the loads that are handled by industrial trucks be trained for these tasks. Nor does either standard require that pedestrian workers who interact with industrial trucks be trained for these interactions. 'Interactions' is understood here to include activities like walking in aisles used also by powered industrial trucks, and working at a work-station serviced by a powered industrial truck, as well as the more well-defined tasks that require a pedestrian to work together with a forklift driver in a shared activity. Our discussants informed us that the lack of training in palletizing and in "how to behave around forklifts" is a definite factor that contributes to severe hazards. Thus it would not seem amiss to require that those responsible for forklift-load formation, and all pedestrian workers who interact with industrial trucks in the senses just mentioned, receive special emphasis on these aspects of their jobs as an important part of the instruction they receive for doing their jobs properly.

Standards of Truck Design

ANSI B.56.1 paragraph 421 on overhead guards specifies a clearance of 74" between the top surface of the driver's platform and the underside of the overhead guard on standup rider trucks, and a clearance of 39" between the top of the driver's seat (not the seat-back) and the underside of the guard on sitdown rider trucks in the 1969 edition. The corresponding paragraph of the 1975 edition specifies the same clearances, and allows the clearances to be adjustable downward for low-clearance applications of the truck. Unfortunately, our investigations show that these clearances are not always adequate. For a graphic instance of this claim, see Plate 4-11c; the 1975 standard does not explicitly allow upward adjustability to accomodate taller drivers. It can be argued that these are minimum clearances, and manufacturers are perfectly free to build in greater ones. But one feels prompted to ask if manufacturers actually do build in significantly greater clearances as a general rule, or only on special order; are upwardly-adjustable clearances an extra-cost item? If so, it seems safe to suppose that very few users who need them will adopt them.

But complaints about cramped driver compartments are not limited to overhead clearances. They implicate foot-room, knee-room, overall leg-room, hip-room and elbow-room as well. The cramped quarters would probably not present a great safety problem in themselves if drivers were regularly called on to drive the trucks for only a few minutes in succession in every hour. But our discussants mentioned quite frequently that they are called upon to drive for rather long periods at a time. They said that in the course of this time, they need to shift position to avoid muscle cramps, particularly in the legs, and so they need to dangle extremities out the back or outside the running lines of the truck to stave off discomfort. They are often aware of work rules and OSHA regulations against this practice, but if the other alternative is leg cramps, the choice is clear. Some drivers of narrow-aisle reach trucks (a variety of standup rider truck) said their operating platforms are so small they cannot get their feet all the way onto them when standing in normal operating position.

Accordingly, it seems in order for future truck-design standards to be restated along lines like the following: driver compartments should be roomy enough to accomodate male drivers at the 95th centile for such body-measures as height, girth, foot-size, arm-length, leg-length (etc.) with comfort; clearances should be adjustable by the user to fit comfortably even larger drivers and smaller drivers to the point of females on the 5th centile for the body-measures stated. Due consideration should be evident in the design for the need to drive the truck for long periods at a time.

ANSI B.56.1 1969 specifies the maximum pedal-pressure that a truck's service brakes may require. For pedals one depresses to actuate the service brakes, the maximum pressure is given at 125# (about 543 Newtons). The 1975 edition allows a maximum pressure of 150# (about 651 Newtons). A recent study (Hansson 1975) indicates that these figures are too high. The study found a mean maximum pressure among males to be 655 Newtons (just above 150#) and for females 404 Newtons (about 93#). Hansson feels that standards should allow a maximum pressure of 250-300 Newtons (up to about 70#) in order to be well within the capabilities of the average female forklift driver. If Hansson is right on this topic, it seems likely that the standards for maximum effort in actuating other kinds of controls should be reviewed as well. Further research is needed before establishing a revised standard, however, and this subject will be discussed later in this chapter.

ANSI standards for truck design do not address at all the matter of padding in driver compartments of standup trucks and on driver seats of sitdown trucks. Our investigations turned up a rather large number of complaints, most of them not explicitly solicited, on just these matters. Poorly padded and poorly contoured driver facilities were said to contribute to a wide assortment of aches and pains, and to some other hazards as well. This is particularly the case, our discussants said, when they are called upon to drive the trucks for long periods at a time, as it appears they often are. It would not seem harmful, then, if the standard were to require that truck-designers devote some attention to these matters in the design of all rider-controlled trucks. For even the smallest ones are subject to being driven for long periods without a break. While a great deal of research would be needed to set specific values for padding and contouring, it would not be remiss for the standard to require that the trucks as provided to users evidence due consideration to driver comfort for long driving-periods in the design of padding for driver compartments on standup trucks, and padding and contouring of drivers' seats. Such a provision could have the effect of ensuring that all makers of industrial trucks, not just the most progressive ones, devote some energy to these matters, thereby spurring perhaps some rises in the current state of the art.

ANSI standards do not address matters of visibility with a separate paragraph on the subject. Although this study does not indicate that visibility is the gravest design-weakness, another recent study (Laumann 1977) indicates that perhaps it is. Conversations with manufacturers of industrial trucks indicate that visibility is very high indeed on their lists of concerns. It might be appropriate to include in the standard a separate clause to the effect that trucks shall be designed to as to provide the driver with the greatest possible visibility in all directions, and modifications of the truck that affect visibility shall not be made without express written authorization by the manufacturer. It would probably be inappropriate to set a more specific standard. This researcher's experiences with an international standards-setting group indicate that there is doubt about the adequacy of current methods of testing for visibility, and until the experts reach a consensus about better ones, it would seem unwise to establish specific standards.

ANSI B.56.1 standards set out some guidelines for the layout of both hand-operated and foot-operated controls on various kinds of trucks. These guidelines are rather broad and general, however, and would naturally allow a good bit of variation from one make and model of truck to the next. We encountered these make-to-make variations as factors contributing to hazards in the case of means of actuating service brakes on standup rider-controlled trucks, especially in contexts where drivers are called upon to drive two or more different makes of truck, often in the same shift. Drivers told us that in such conditions, a driver could become confused about how to brake his truck and cause real problems, especially if the driver is inexperienced. We encountered some models on which there is one foot-pedal; it is sometimes to be depressed by the right foot, on other trucks by the left foot. On other trucks yet, the pedal serves as a deadman brake, that is, it must be depressed in order for the truck to travel, and releasing it actuates the brakes. This pedal can be operated on some trucks by the right foot, on some by the left foot, on others by either foot. This control is often not a pedal but a button. On other kinds of trucks yet, there are two pedals, one of the deadman sort, the other to be depressed as the service brake. Which foot is to actuate which pedal can differ from one make or model to the next. Drivers told us also that when a truck has an upward-movement braking means, it is possible for him to have both feet on it inadvertently, so that when one foot is lifted, an apparent brake-failure occurs - but is undetectable on further investigation. Despite these findings, we would argue against requiring greater uniformity in this connection, on grounds to be brought out below.

Standards Addressing Themselves to Drivers

A great many clauses of 1910.178 require specific behaviors (often refraining-type behaviors) of drivers of powered industrial trucks, whether the clauses' wording is addressed to the employer or the driver. The outstanding examples of such clauses are the one that requires drivers to slow down and sound the horn at intersections (i.e. clause (n)(4)) and the one that requires drivers and others to refrain from placing hands and arms between the uprights of the mast and to refrain from dangling extremities outside the running lines of the truck (i.e. clause (m)(4)). It is of course a good practice to give warning when one approaches a place where vision is obstructed, and a bad practice to place extremities outside the running lines of the truck or between the uprights of the mast. The discussion in the section of this chapter entitled Some Common Factors indicates several conditions that can prompt drivers and others to violate these clauses; the clauses as they are written do not evidence consideration of these conditions. What is unfortunate about the clauses as they are written is that they allow employers to gain the impression that they can comply with the clauses by merely establishing a workrule to the same effect as the clauses, without addressing the conditions that prompt workers to violate such rules. The two clauses just mentioned here are not the only cases in which this matter comes up: the sub-clauses of (m), of (n), and of (o) are replete with requirements aimed ultimately at the workers themselves.

It is doubly unfortunate that it is not immediately clear how such clauses could be altered to show proper consideration of the conditions that impede and limit compliance with them. It is clear that this matter is an appropriate subject for much further study. It would seem to be helpful, though, if inspectors were provided with the techniques necessary to ferret out the reasons why the behavioral/operational missteps they observe are occurring in the plant, and address these reasons by citing the other appropriate standards, or by other appropriate action.

Matters not Appropriate for Standards-Setting

In relation to the inadequacies of truck-design standards that we noted above, it is probably not appropriate at this time for the problem to be solved by spelling out specific values to the requisite variables. In the case of most of the "weak" standards discussed just above, it would appear that not enough is established as certain knowledge in the scientific and engineering communities to ensure that the values one could provide now would be the proper ones. This is particularly the case in connection with the problem of visibility from the driver's normal operating position. There are some scientific problems to be resolved in connection with pedal-pressure requirements, too: one engineer noted that a healthy adult can exert as much as 1500 Newtons (or nearly three times the current maximum allowed by ANSI B.56.1 1969) in a panic situation. It is not immediately clear how this fact and the results of Hansson's study should both be taken into proper consideration in setting a standard. There are also engineering problems, viz. how to allow a low maximum-pedal-pressure requirement in the design of a truck's brakes and still prevent the wheels from locking up when the brakes are applied in a panic. Nor is it clear that there is enough reliable knowledge available to set specific values for padding of driver compartments, and padding and contouring of drivers' seats.

This researcher argues that it would be inappropriate for standards to require greater uniformity in the layout and means of actuation of service-brakes on standup rider-controlled trucks. In other connections, manufacturers argue that the ways in which their designs for pedal-layouts deviate from the usual layout of pedals in automobiles offer distinct operating advantages. And in some degree drivers tend to agree with the manufacturers. Requiring greater uniformity would likely serve, then, only to make it more difficult for a driver to be provided with the truck that meets his needs best.

No great need to require greater uniformity is apparent to this researcher. The problem can be met at the level of the truck-user (owner or lessee) in a great variety of ways: in the selection of trucks for use in the plant; in the ways that trucks and drivers are assigned to operations and to each other; in the training and supervision drivers receive; in the experience-requirements established for drivers in certain operations or departments; in the work-schedules and production-rate expectations drivers are called upon to meet; and by other approaches besides. It would seem morally incumbent on the truck user, however, to address the problems posed by the non-uniformity of service-brake layout and means of actuation in some effective way, where the problem exists.

Some factors disclosed by this study as contributing to forklift hazards and not addressed by standards include matters not related in any obvious way to the design of the trucks. These other areas perhaps ought not to be addressed by safety standards. In this category would seem to fall matters like production-speed stress, pay-scales and job-prestige levels, and the ways in which trucks and drivers are assigned to operations and to each other. These factors affect many facets of plant operations in addition to industrial-truck operations, and do not obtain in all plants. Where they are hazard-making factors, the ways in which they arise and contribute to hazards can vary almost incredibly. In addition, many of these matters are commonly held to be within the sphere of labor-management relations or management prerogative rather than the safety sphere, and this study alone is certainly not sufficient ground for overriding this common view. Since the foundations of these factors, where they are problematic, vary according to conditions in and about the plant, it would appear most appropriate for them to be addressed at that level. It would seem morally incumbent, however, on both workers and management to identify such problems where they exist, trace them to their roots, and deal with them in some effective way.

SUBJECTS FOR FURTHER STUDY

The present study probably succeeds in suggesting topics that deserve painstaking investigation in their own right at least as well as it succeeds in exposing human-factors roots of forklift safety problems. The topics that arise at various points in this study would appear to be appropriate matters for several different groups. In what immediately follows, items will be suggested for investigation by NIOSH, by NIOSH or OSHA, by OSHA's training section, by OSHA's and ANSI's standards-writing sections, by a special task-force of some appropriate sort, by the Bureau of Labor Statistics, by truck-manufacturers and/or their trade associations, by truck-manufacturers and their dealers, and by plant managements.

Items of Potential Interest to NIOSH

The present study indicates that there is a good deal of scientific work that can well afford to be done with the goal of understanding the relationship between factors and hazards, evaluating the exact contribution of various facets of ergonomic design to accident-occurrence and -prevention, and establishing what would be the avenues of approach most likely to bear fruit in preventing the most important kinds of industrial-truck accidents.

1. The present study has shown 38 factors that commonly contribute to forklift hazards. The model of hazard management that has guided this study (see above Chapter 2) focusses on the worker and work-team as the primary locus of control of the conditions affecting tasks, and thus defines a hazard-making factor as one that would render workers' control of these conditions difficult. The present study shows only that these factors do render control by workers difficult, but is not able to show exactly how control is rendered difficult. There are of course many ways control can be made difficult, including the following: (a) lack of relevant sensory or general information; (b) overload of sensory or kinesthetic feedback information; (c) inconsistencies in the information; (d) neurophysiological impediments to the formation of appropriate control-judgments; (e) poor feedback-compliance of the tools and equipment used; (f) neurophysiological or mechanical or spatial or temporal impediments to the execution of appropriate control-judgments. What remains to be established is which factors contribute in which ways to the workers' difficulty in controlling conditions in and about their tasks.

2. The present study indicates that the factors that contribute to forklift hazards are many, complex, and likely to interact with each other and with conditions that in themselves are unproblematic, in a bewildering assortment of complex ways. The present study shows that these factors can have their roots at various levels of authority, and thus that accident-prevention efforts exerted at various levels can help a great deal. But this study

has not been able to reveal many useful generalizations about which factors can be addressed most effectively at which levels and in which ways. Industrial-truck drivers and the pedestrian workers with whom they interact bear the ultimate responsibility for controlling conditions of tasks in forklift operations, and it is they who in the end will be called upon to implement and cope with whatever accident-prevention steps are taken at other levels of authority.

Recent studies show (Gottlieb 1976, and Coleman and Smith 1976) that workers are well aware of hazard-making factors and of the effectiveness of safety measures currently taken. Thus it would seem appropriate to learn from these workers, their foremen, plant engineers and managers what general avenues of approach to accident-prevention are most likely to bear the greatest fruit. These persons can be asked whether worker training (and on what subjects), or better supervision, or standards-writing by government, or changes in the truck or loads or physical features of plants would wreak the greatest good in preventing such frequent and severe accidents as loads falling on bystanders, pedestrians being struck or pinned by industrial trucks, and in eliminating such factors as co-workers riding on the truck or load or forks or empty pallet. Results of such a study could conceivably be invaluable in guiding accident-prevention efforts at all levels concerned with industrial-truck operations.

3. Some experiments would seem to be in order for the purpose of assigning a precise value to the effect of ergonomic-design improvements on forklift accidents. Researchers could select some trucks with designs that appear to provide poor forward visibility, some trucks with apparent poor rearward visibility, some trucks with apparently cramped driver compartments, some trucks with apparently thinly-padded seats, and some trucks with apparently poorly contoured seats. Accident-rates and near-miss rates for such trucks could be compared against accident- and near-miss-rates for trucks with apparently better designs in these regards. Variables that would appear to require accounting for in the experimental design would seem to include the effectiveness of the maintenance-system for the various trucks, physical characteristics of the drivers, visibility characteristics of the locations in which the trucks are used, and the drivers' perceptions and attitudes concerning design-weaknesses of their trucks in the respects tested.

4. Experiments would be in order also to establish appropriate values for the physical effort required to operate the various foot- and hand-controls on trucks. It would be important to establish not only mean and median values and ranges of maximum effort exertable by males and females, but values for effort exerted in panic-situations as well. Candidates for testing would appear to include downward-movement pedals, upward-movement pedals, controls to be squeezed by the hands, controls to be pushed by hand-and-arm movement, and controls to be pulled by

hand-and-arm movement. In the case of controls to be squeezed by the hand, it would be important to take into consideration the clearance between the fixed element and the movable element, since womens' hands tend on the whole to be somewhat smaller than mens'. Results of such experiments could be extremely helpful in determining specific design-standards for trucks.

5. Experiments would be called for to determine the exact nature and extent of the effect on drivers' ability to control their trucks arising from the need to lift one foot to actuate service-brakes on standup-rider-controlled trucks. As noted elsewhere in this report, lifting the foot to actuate the brakes would tend to throw the driver somewhat off-balance. The adjustments of postural movements necessary for a driver to keep his balance could conceivably affect adversely the driver's ability to make the major-limb movements and manipulative movements needed to control the truck properly. This situation may or may not have an important effect on controllability of the truck, since many current designs call for at least one of the driver's hands to be resting on a control that is supposed to be stationary with respect to fore-and-aft travel of the control while the truck is travelling. To determine the exact nature and extent of the balance-while-braking problem, it would be important to investigate various designs and layouts of hand-controls in relation to different pedal-layouts (right-foot actuation vs. left-foot actuation) and means of actuation (by releasing the pedal vs. by depressing it).

Topics for NIOSH and/or OSHA

Items of potential study-interest for either NIOSH or OSHA or both relate to matters that probably cannot be spelled out very specifically in a general-industry standard on powered industrial trucks. As the present study shows, practices and needs in such areas as worker-training, types of overhead-protective devices, adequacy of maintenance-systems, adequacy and appropriateness of warning devices, and numbers and kinds of attachments and accessories vary tremendously from one plant to the next. It would undoubtedly be quite unfeasible to attempt to cover all the possible variations of plant-needs within the standards themselves, and so the standards are phrased in very general, non-specific terms. Yet it would appear that employers need to gain a rather specific idea of what they can and should do to come into compliance with the spirit of the clauses. Thus it would seem helpful to bring out some specific guidelines of an advisory, not compulsory, nature on the following topics.

1. What constitutes a very good system for educating workers in those portions of their tasks that involve industrial trucks? Guidelines should cover such important sub-topics as content and methods of training, amounts and kinds of supervised practice prior to full authorization for industrial-truck tasks, licensing, refresher-training, re-licensing, progress toward general authorization for all industrial-truck tasks, and procedures for selecting workers for industrial-truck tasks. The present study sug-

gests that not only drivers need education for their tasks, but also mechanics, those who form loads for industrial-truck transport, pedestrians who act as helpers for drivers, workers whose tasks are supplied by industrial trucks, workers whose tasks involve working in close proximity to industrial-truck traffic, and any employee who has rather frequent occasion to move about in aisles where there is forklift traffic. In this researcher's view, task-education guidelines should be constructed for these kinds of workers also.

2. What constitutes an adequate system of maintenance for the trucks?

3. What kinds of overhead-protective devices are best for what kinds of application in handling what kinds of goods, and what would constitute keeping these devices in adequate repair and in use when and where needed.

4. What kinds of warning-devices work best in which general kinds of industrial settings. It is rather obvious that one kind of warning device would be called for in a paper mill's rarely-used basement, while another is far better in the center of a steel-forging operation.

5. Numbers and kinds of attachments and accessories for handling different kinds of loads always in a safe way, and for blocking wheels of highway trucks and railroad cars.

Surveys of drivers, pedestrian workers, and plant engineers in different kinds of industrial operations could be extremely helpful in developing the guidelines; the guidelines could also serve as indicators of experience in the field as to what kinds of devices and systems and approaches work effectively and which do not.

Guidelines should be written in non-technical, laymens' language for use by managers, safety officials, and even the workers themselves, in individual plants.

NIOSH has completed some work of this kind (cf. Anonymous 1975) in the area of content and methods of training industrial-truck drivers. But it would appear that more is needed, and in other areas as well.

For Trainers of OSHA Inspectors

We noted above in the section of this chapter on Factors and Standards that there are quite a number of clauses that call for certain behaviors and procedural steps on the part of drivers of industrial trucks and sometimes their co-workers. Compliance with some of these calls for expert judment on the part of drivers. If these clauses are to be properly enforced by inspectors, the inspectors must have good judgment in these matters as well, and must know how to obtain the information necessary to make good judgments.

The present study has not sought specifically to evaluate the performance of OSHA inspectors in connection with industrial-truck operations, but some tentative conclusions can be drawn: many important areas are being given emphasis in inspections, but some standards are not cited as often as they seen to deserve to be. From the data available during this study, it cannot be confirmed or disconfirmed that the most important factors are being identified in the violations cited in inspections. In order to ensure that the genuinely important factors in the plant are indeed detected in inspections, and that behavioral/operational requirements of drivers and co-workers are being enforced in due extent, it would seem helpful if OSHA inspectors were to be thoroughly schooled in the following matters:

1. The basics of forklift operations, from load-formation through actual driving and load-handling to repair of the trucks;

2. The use of the plant's safety-data to identify potential trouble-areas for the safety of forklift operations in the plant, and the use of general data to gain advance knowledge of the most important kinds of forklift-safety problems;

3. Techniques for using expertise available in the plant from engineers, workers, foremen, and others, to trace actual violations detected to their roots, cite the correct clauses, judge the adequacy of maintenance, numbers and kinds of attachments and accessories, adequacy of warning devices and of worker-education in the plant for their industrial-truck tasks, and to judge properly the compliance of drivers and co-workers with the behavioral/operational requirements of the standards.

It is clear that a great deal of development-work is needed to provide OSHA inspectors with these skills. The expertise used in this development work could also be tapped to provide employers a consultative service, in which they could submit their forklift-safety systems and plans for expert review and comment without fear of immediate citation and penalty.

For Standards-Writing Activity by OSHA and ANSI

As noted above in the section on Factors and Standards, some improvements in the standards to seem possible. To a large extent, the changes that seem to be called for consist of alterations in the language of some clauses to make them clearer, and a few additions in order to address better some noteworthy hazard-making factors. Clauses (n)(15), (k)(4), and (m)(12) would appear to be candidates for wording changes. Clauses (m)(12), (k), (q)(1) and (o) would appear to stand in some need of completion. In addition, it would seem prudent to add clauses requiring that workers who interact with industrial trucks as part of their usual tasks receive some education in the proper and safe accomplishment of these tasks. Some careful study on these matters in their own right would of course be called for to determine the advisability and feasibility of such changes, as well as their specific content.

We noted earlier some issues in the standards related to the design of trucks that would seem to need review. These issues include the following: clearances among components in the drivers' compartments of trucks, maximum allowable physical effort required to actuate and manipulate various controls on the truck, visibility from the driver's position, padding in drivers' compartments, and the padding and contouring of drivers' seats. In most of these issues, a great deal of ergonomic research needs to be done before specific values can be set in the standards, but it does seem appropriate that interim clauses be drafted to require that manufacturers devote significant attention to these matters in designing their trucks. Careful consideration will need to be given to the advisibility, feasibility, and specific content of these interim clauses as well.

The ANSI B.56 committee would seem to be the most appropriate body to consider changes in truck-design standards, but some provision should be made for incorporating revisions in the ANSI truck-standards into the OSHA standard as these revisions are made.

For a Special Task-Force

The present study indicates that powered industrial trucks tend to remain in service long beyond the eight-to-ten year useful life anticipated by many truck-manufacturers. This finding implies that there is a great gap between the state of the art of ergonomic design of trucks as displayed on the dealers' showroom floors and the state of that art as it is encountered by the workers who drive and otherwise interact with powered industrial trucks. Our investigations turned up several interesting complaints related to ergonomic design features of trucks, but it was noted that most of these complaints pertained to rather older trucks. Assuming that truck-users' patterns of practice in replacing trucks are not likely to change significantly, we can readily draw the conclusion that drivers will be called upon to cope with these poorer designs for quite some time yet. It would seem helpful toward alleviating this situation if manufacturers were to devise and provide update-kits for various aspects of older trucks in which design has made significant progress.

Conversations with representatives of truck manufacturers reveal that some such efforts have been attempted. Some update-kits were developed and provided to users at a cost somewhat below the manufacturer's cost of providing them. The manufacturers' representatives said the kits were a commercial flop. They also said that manufacturers themselves could not possibly absorb the full costs of developing, providing and installing such kits.

It would seem helpful, then, for a task-force to be formed to devise ways in which positive incentives could be provided to ensure that drivers of powered industrial trucks have in their hands equipment that is as near the current state of the design-art as humanly possible, and use it in the most effective ways. Manufacturers should have incentives to develop and provide update-kits that improve the ergonomic features of existing trucks as well as the reliability and effectiveness of other truck-components such as brakes, clutches and transmissions, hydraulic systems, and power-assists for various truck controls. Truck users should also have some positive incentives to have the available devices installed and to instruct their workers in how to use these new devices effectively and safely. Clearly a great deal of careful study will be needed to determine what forms such positive incentives could feasibly take.

For the Bureau of Labor Statistics

The BLS currently has, through its Supplementary Data System, some capability for statistical tracking of industrial-truck accidents, and some means are currently available for monitoring the practices of inspectors in connection with industrial-truck operations. These capabilities could be drawn together and supplemented with causal information on industrial-truck accidents to form a nation-wide data base on forklift safety. Frequency and severity of certain kinds of truck-related accidents could be measured for various regions or time-periods or sectors of the economy, and trends could be detected. Such a nation-wide database could be extremely helpful in setting priorities for truck-accident prevention efforts and tracking the effectiveness of such efforts. This researcher's experiences with the current data-sources indicate that much careful study will need to be devoted to the planning of such a nation-wide data base. There have been a good many thorny problems to be dealt with in current efforts at improving the SDS.

For Manufacturers of Industrial Trucks

As has been indicated previously, there are several areas of truck design in which manufacturers would seem well-advised to carry on continual research-and-development work toward improving their product. Some of these areas would be as follows:

1. Visibility from the driver's position.

2. Foot-room and knee-room and hip-room and leg-room and elbow-room, as well as head-room in drivers' compartments. Ever-better means need to be found to accomodate drivers of widely varying sizes and shapes in comfort.

3. Location, quality and quantity of padding in drivers' compart-

ments and padding and contouring of drivers' seats. Design-consideration should be given to the fact that drivers are often called upon to remain in their operating positions for long periods of time without relief.

4. Development of update-kits for any aspect of older trucks in which design has made significant strides, including ergonomic matters as well as matters of reliability and serviceability.

5. Means of reducing by engineering and truck-design the likelihood that a driver or co-worker would be severely injured if he were to place hands or arms in what are now pinch-points around the mast. The limiting consideration here is of course visibility. How to eliminate or guard pinch-points around the mast without detracting from visibility from the driver's position is a problem that calls for sizable amounts of ingenuity.

6. Better means for mounting and dismounting sitdown rider trucks. A recent study (Laumann 1977) indicates, and the Workers' Compensation data reviewed for the present study somewhat confirms, that notable numbers of injurious falls from trucks can be traced in part to poorly designed means of mounting and dismounting the trucks. Laumann points out that current designs that employ flat vertical sides for the truck do not lend themselves readily to building in good steps up to the driver's platform. He notes further that, although steps could be cut into such truck-sides, these steps would not be visible from the driver's seat, and would have to be felt around for with the foot for dismounting. Laumann also suggests that handgrips at appropriate heights could be attached to the left-front upright of the support for the overhead canopy, so that the driver would not feel called upon to reach for the steering wheel - which provides an unstable grip at the best.

For Truck Manufacturers and Their Dealers

Conversations with makers and dealers of industrial trucks indicate that these bodies engage in significant efforts to learn of their users' problems with their trucks and respond to these pieces of information. The scope of these efforts includes not only technical information and help with maintenance problems, but training materials for drivers and mechanics as well. But conversations with users and drivers and mechanics, as well as a brief review of some court cases, indicates that communications between users and providers can sometimes be inadequate in quantity or quality or scope. Manufacturers and dealers do not appear to be active in helping users with all of the problems involved in the 38 factors identified in the present study, and it may be that truck-providers have expertise and contact with expertise in areas where they are not now offering these things to their users (cf. the paragraphs noted in the Commerce Clearing House Products Liability Reporter).

Accordingly, it would appear helpful for truck-providers to put their already significant efforts at soliciting feedback from users and drivers and mechanics on a regular and systematic basis, and set the scope to include any and all factors that contribute to hazards in the various aspects of truck operations. A rigorous survey of users' safety problems and needs could be extremely helpful in determining priorities for aspects of truck design, indicating ways in which existing customer services could be improved, identifying matters in which technical information is needed in greater quantity or different form, and identifying problems in which truck providers could help by facilitating contact between users and other experts. Such a regular and rigorous survey in broad scope could supply truck-providers a way of ensuring that their good efforts are well-directed.

For Plant and Firm Managements

Our conversations with plant managers, safety officers, and plant engineers show that salaried employees are indeed aware of a great many of the concerns voiced by drivers and mechanics and pedestrian workers about the factors that contribute to forklift hazards. But it does seem to occur sometimes that some matters are not brought to the attention of managerial personnel, and it seems that more frequently, the knowledge of managerial persons is not communicated completely or effectively to the drivers and mechanics and pedestrian workers. Since it is these latter workers who must perform their tasks under existing conditions and control existing hazards, and must in the end cope with whatever control-measures are instituted, and since these workers are extremely valuable sources of information on hazards and the effectiveness of current control-measures (cf. Gottlieb 1976 and Coleman and Smith 1976), it would seem appropriate for plants and firms to institute a system that makes effective use of workers' knowledge.

Accordingly, it would be in order for plant managements and firm managements to survey workers involved in industrial-truck operations on a regular basis in systematic fashion. Such a survey can reveal much in the way of hazards and factors that constitute problems in the safety of industrial-truck operations in the plant. Results of the survey can be posted and updated with information about developments related to the hazards and factors identified, so that the workers themselves can monitor the subjects of their concerns. Results of such surveys can be extremely helpful in setting priorities for forklift-safety efforts, in identifying points at which planning for changes could fruitfully involve worker input, and in evaluating the safety-performance of all sectors of the plant and firm in connection with forklift-operations.

Since the specific conditions that give rise to factors which contribute to hazards and accidents in forklift operations vary so greatly from one plant to the next, and since many of them are subjects on which precise safety-laws cannot be written, it is appropriate that the management of these conditions be done at the point at which they arise - the plant or firm. Effective management depends of course upon having good information about factors and hazards, and the information needed can be gotten in largest measure from "the horses' mouths" - i.e. the drivers and mechanics and pedestrian workers themselves.

HAZARDING A CONCLUSION

This study was intended to identify some important human factors that play a causal role in accidents that involve powered industrial trucks. We began with the assumption that human factors is a very broad area that includes a great many things besides ergonomic design of the trucks. (See above, Chapter 2). Accident data were analyzed to discover the main kinds of frequent and severe accidents involving powered industrial trucks, and subsequent examination of causal information regarding these accidents, and of the comments our discussants made during conversations in the field were directed toward the discovery of as many factors involved in forklift hazards and accidents as possible.

This method was intended to accomplish two things: (a) to allow for the possibility that various aspects of ergonomic design of powered industrial trucks might appear as factors contributing to hazards and accidents in areas that one might not suspect intuitively: (b) to allow us to gain some perspective on the importance of ergonomic-design features of powered industrial trucks relative to other factors that contribute to hazards and accidents. Both aims were accomplished.

Unsuspected Involvements of Human-Factors Design of Trucks.

Several things were learned about the ways in which ergonomic and human-factors design of powered industrial trucks contributes to hazards and accidents. Some of them were quite surprising. We learned, for instance, that LPG-powered trucks are rather rarely equipped with a fuel-guage on the dashboard, so that a driver can easily run out of fuel with a load elevated 10 feet in the air. We learned that the brake-design on a standup rider truck that requires the driver's foot to be lifted from a pedal can be a part of an actual brake failure in which no defect can be found in the brakes on later investigation. It can be the case that, in some such instances, the driver inadvertently had both feet on the pedal, so that lifting only one would fail to actuate the brakes.

We found that generally cramped driver compartments, particularly on standup rider trucks, but also somewhat on sitdown rider trucks, are occupied by drivers for long periods without stopping; in order to gain some comfort by shifting positions, drivers sometimes dangle feet and legs out the back of standup rider trucks, and dangle extremities outside the running lines of sitdown rider trucks.

We learned that overhead canopies on order-picker trucks are sometimes designed too low for tall drivers and are not readily adjustable upward.

We learned that the upright supports for overhead canopies can be sloped backward too far, making it easy for a driver to bump his head while getting on or off the truck.

We found also that the offset of the driver's seat to the left of the trucks, coupled with the presence of a rather large spool for hydraulic lines on the right front upright for the overhead canopy can make it difficult for the driver to see obstructions and moving objects on the right of the truck.

We learned that it is uncomfortable to turn around to look in the direction of travel while backing a sitdown rider truck, which can explain somewhat why drivers often back up without looking.

We found that lack of padding can be a factor: drivers' platforms on standup rider trucks are rarely padded very thickly, and when one is required to operate the truck for long periods, achey feet, leg cramps, and lower-back pain can ensue, drivers' seats, particularly on older trucks, are rarely contoured to the body shape, often lack lower-back support and thigh support, and are often poorly padded, which leads to sore derrieres and to back pain, particularly when one is required to operate the truck several hours in succession, as seems rather common. Drivers noted that the lack of springs and shock absorbers on the trucks exacerbates the lack of padding where the driver's feet or sitter contacts the truck. Drivers said that the discomfort generated by these design features, in combination with littered and bumpy driving surfaces, decreases driver attentiveness and can contribute to all sorts of hazards and accidents.

In light of these findings, and of those of another recent studies (Laumann 1977), (Hansson 1975) several areas related to truck design would appear to be worthy of further study: (a) anthropometric considerations, such as distances between the driver's trunk and components of the driver compartment: knee room, foot room, hip room, distance of canopy to seat or top of driver's platform, positioning of canopy uprights with respect to head clearance while driver is mounting or dismounting.

(b) improving driver comfort, particulary in regard to padding and contouring of seats, padding of driver platforms, and feasibility of allowing trucks' suspensions to absorb some of the jolts.

(c) visibility all around the truck, but most particulary through the mast.

(d) proper levels of pressure required to operate the truck's brakes, and the attendant problem of preventing lockup of the braking wheels.

(e) improving the means of mounting and dismounting the trucks.

(f) the exact extent to which the incorporation of foot-actuate brakes in the design of standup rider trucks contributes to hazards and accidents, and the possibility of eliminating this feature.

(g) making the markings of controls more durable.

(h) instrumentation on truck dashboards.

As noted above, these matters should be the subjects of ongoing research that would aim at continually making improvements in these areas of truck design. Although truck design has made great strides forward in most of these areas in the last few years, manufacturers have admitted to us that they realize that there is a long way yet to go, and that fresh breakthoughts are always in order. For this reason, it does not seem fruitful to attempt to set standards in these areas.

There is yet another matter related to truck design that was occasionally noted as problematic: the layout of controls, particularly the means of actuating the brakes. Although the ANSI standard for powered industrial trucks (B.56.1) sets some general requirements for layout of controls and means of actuating them, significant differences are encountered among makes of truck. When drivers, particularly inexperienced ones, are called upon to operate more than one make of truck, these differences can lead to confusion, and thereby to hazards and accidents. However, it does not seem that it would be fruitful to make control layouts and means of actuation more uniform, either by standard or by industry agreement. Manufacturers argue, and to some extent drivers agree with them, that the features peculiar to their trucks can offer drivers some noteworthy advantages. It should be noted also that making control layouts and means of actuation uniform beyond what ANSI standards now call for would make it more difficult for users to select just those trucks that suit their operations and drivers best.

The problems presented by non-uniformity in control layouts and means of actuation can be combatted on other levels: drivers and foremen can allow themselves a little extra time to accustom themselves to the peculiarities of the trucks they need to use; users can devote attention to the non-uniformity problem when selecting new trucks; users can institute some changes in job-design to prevent drivers from using more than one make of truck.

Putting Ergonomics into Perspective.

Although the foregoing paragraphs concern themselves with several items of human-factors design of powered industrial trucks that do contribute to hazards and are of some technical interest, they represent a rather minor segment of the large mass of contributing factors. Other factors were mentioned much more frequently and much more strongly than design inadequacies in the trucks, and the contribution of these other factors is a great deal clearer than the contribution of truck design.

The age and state of maintenance of the trucks is a factor that was of much greater concern to our discussants than any features of truck design. A poorly maintained truck can contribute to a vast number of different kinds of hazard, and an old truck is more difficult to maintain in proper operating condition than a relatively newer one. Maintenance departments can perform poorly for a number of reasons, not all of them under any influence of the driver who must use the truck. It may also be the case that managers are not adequately aware of the problems posed by old, worn out trucks, and thus do not replace the trucks often enough. As we noted above, it would appear that most of the trucks in actual use in material-handling tasks are quite old. This means that there is a large gap between the state of the art in truck design and what drivers are called upon to cope with, and this fact in turn tends to limit drastically the impact that design improvements can have on accident prevention. This impact is also dependent upon the performance of the plant's maintenance department, the level of training and experience and skill of the drivers, and upon the actual operational requirements of material-handling tasks to be perfomed in the plant.

The nature and condition of the load to be moved was of great concern to our discussants. The problem mentioned most frequently was the way in which the load is palletized. The load can be formed so that part of it overhangs the pallet, or contains empty spaces so that upper items are not supported by lower items, or it can be unsecured against internal movement, or not secured to the pallet adequately; it can also be loaded on a pallet that has boards missing or broken. Some of these conditions can remain hidden from the driver, but even when they are known, the driver can find himself called upon to move the load anyway. The roots of this problem can be traced in part to those responsible for forming the load in the first place, and in part to those who make the decision to move unsafe loads without altering them. The driver himself is not always found at these roots.

Certain physical features of the workplace were also found to be quite problematic. Chief among these appears to be aisles that are crowded and cluttered with interim in-process "short-term" storage of goods. This condition can be brought on by an operations-design that calls for in-process storage along aisles that may be too narrow to begin with, by an operations-design that calls for loads being handled by two or three different kinds of truck before they arrive at their place in the storage racks or inside the highway truck or railroad car, and by overstocking the plant with goods and materials. Piece-meal rearrangement of production machines and operations can play a part here as well. These problems are often complicated by the state of maintenance of the trucks, production-speed stress, and non-defensive walking and working practices of pedestrian workers who find themselves in areas where industrial trucks operate. Here again, the driver is called upon to adjust to conditions that, for the most part, he did not create himself.

The condition of the driving surface appears as an important factor as well. Water and oil and debris on the floor from industrial processes, water blown onto the loading dock by the weather and dripping from objects stored outdoors then brought inside, bumps and cracks and dips and potholes in the floor, and leaks of transmission oil and hydraulic fluid from the trucks themselves all pose obvious problems. The condition of the driving surface can combine with certain design-features of the trucks that are not obviously problematic in themselves to add up to a large number of very serious hazards. Housekeeping operations are not always adequate to keep ahead of these problems, and drivers rarely have much control over the performance of these operations.

Our discussants mentioned quite a number of operational/behavioral missteps as contributing in important ways to hazards. Drivers sometimes back up without looking first, turn corners too fast, travel forward with the load blocking their vision, and fail to warn others of the truck's presence. Pedestrian workers sometimes appear in front of trucks from doorways and side aisles with no advance notice to the drivers, fail to hear or heed warnings given, and act as if they always had the right of way regardless of other relevant conditions.

Most important among these operational/behavioral missteps would appear to be these three: (a) failure to establish and maintain effective communication among workers who are sharing the same tasks or the same aisle space; (b) the decision to have a co-worker ride on the truck, the load, the bare forks, or an empty pallet; (c) the failure to block wheels on highway trucks and railroad cars, to check for the blocking, and to check the bed-surfaces of highway trucks and railroad cars.

Ineffective communication among workers sharing the same tasks or the same aisle-space is involved in several different kinds of hazards, but the need for such communication is nowhere clearer than in tasks that involve complex interactions between an industrial-truck driver and a pedestrian helper. A good example of such a task is unloading goods piled on slip-sheets from highway trucks and railroad cars. The failure to keep in close touch with each other seems traceable in large measure to lack of training. We found that pedestrian workers are rarely trained at all for those portions of their tasks that involve interactions with industrial trucks. Drivers also told us that pedestrians appear to lack important information about trucks and their operational requirements, such as lateral space needed, stopping distances, and limitations to drivers' vision.

The communications-problem combines with, and is partially explainable by several other matters as well: warning devices on the trucks that are inoperative, inadequate, or just plain missing; blind intersections that lack adequate mirrors and signing, and doorways that open directly into aisles; noisey truck engines and noise from production machines to which many workers respond by wearing hearing-protective devices that make it difficult to establish and maintain auditory communication.

Co-workers are sometimes called upon to ride on the back of an industrial truck to act as human counterweight for a load just over the truck's capacity; they are sometimes asked to ride on the load itself when it is much longer than the forks or consists of inherently unstable items like scrap lumber from broken-down pallets; they are sometimes asked to ride the bare forks or an empty pallet to perform odd jobs like unjamming an overhead conveyor, fetching a single item down from a high storage rack, change a lightbulb, or take inventory. These requirements of material-handling tasks seem to arise with little or no advance notice to the workers called upon to perform them. Someone, not always the involved workers themselves, decides also that the task cannot wait for appropriate equipment to be brought to the scene. In many cases, the plant may not own the appropriate kind of truck or attachment, or the needed item may be down for repairs, or currently in use in another part of the plant. The involved workers themselves rarely have much say over the number and kinds and locations of such devices as fork extensions, bigger trucks, clamp-attachments for handling large rolls, or proper elevating work platforms with guardrails and toe-boards, or ladders. They often feel also that they do not dare countermand instructions by a foreman to do something they consider to be unsafe, or to slow down the process by taking the time to bring the appropriate equipment to the scene.

The failure to block the wheels on highway trucks and railroad cars is not one that can be charged to industrial-truck drivers very often. It is rarely they who are assigned this task, but if the wheels are not blocked, this operational misstep can affect the industrial-truck driver in drastic ways. This failure seems traceable in large measure to a shortage of wheel-blocks in the plant. No plant we visited owned enough wheel-blocks to provide two for each bay at the loading dock and two for each bay at the unloading dock, yet we observed times when almost all of the bays were in use at once, and no wheels were blocked at all.

The failure to check for wheel-blocking and poor bed-surfaces appears to be a matter of work-design in the plant. The task of checking on these matters is not always assigned to industrial-truck drivers, and it is not always clear to the workers around the dock who do have this responsibility. Of course, the need to check for blocking is completely eliminated in many plants by the industrial-truck drivers' knowing there are no wheel-blocks in the plant. And it is naturally difficult to check the bed-surfaces on a highway truck or railroad car that is fully loaded; but none of this obviates the need to check on the surfaces of empty trucks and cars, and if no one is aware that he has the job of doing this and reporting to the industrial-truck driver, the latter may lack for crucial information.

Our discussants also talked about several general features attendant upon working in their plants that contribute in important ways to hazards. The list includes such matters as pay-scales and job-prestige levels, the way that drivers and trucks are assigned to each other, production-speed stress, the age and state of maintenance of the trucks, and the training that workers receive for those portions of their tasks that involve industrial trucks. It should be noted that these factors interact with each other and with other factors discussed above in many different ways.

It can happen that, in a plant where production workers are all highly skilled welders and machinists, positions in the material-handling aspect of plant operations are low-status, low-paying jobs which other workers consider to be assigned to those who are generally incompetent for important work in the plant, but cannot be sacked. Workers who are filling positions considered in the plant to be low-pay low-prestige positions tend not to fill them for very long, and their position at or near the bottom of the totem pole provides them little incentive to attend closely to the quality of their work. Supervision of such workers can be very lax as regards quality of performance in the tasks, and strict only as regards quantity of work produced. Positions known to be toward the bottom of wage-and-prestige pecking orders are not generally thought to be ones for which much training is appropriate. This seems particularly true for manual materials-handlers who are often the ones responsible for load-information in the first instance, and the generalization seems to hold to some lesser extent for walkie-truck operators and for the drivers of the smaller trucks in the plant. Workers having a deflated view of the importance of their jobs can explain much in the way of poor palletizing and inattentive performance of many other tasks related to forklift operations.

An attitude of "Oh, what the heck, nobody really cares" on the part of materials-handlers may be prompted by what workers perceive to be management attitudes. In one plant, workers told us management did not care how things were done, just so that they were done quickly. There may also be a connection between poor attitudes on the part of workers and the nature of the goods produced at the plant. It appears from a large number of visits to a great many different kinds of plants in connection with this and other research projects, that plants producing inexpensive goods with rather wide margins for tolerance for a mass market tend to employ rather lower-skilled workers at rather lower wages, offer them less training, and emphasize quantity of production often to the detriment of quality and safety. On the other hand, we have noted that plants producing high-quality goods for a well-defined specialty market tend to employ rather higher-skilled workers, pay them rather more, train them somewhat more, and set higher standards of performance for them as regards both quality of work and safety, even in materials-handling tasks.

Production-speed stress imposed on drivers of industrial trucks is another systems-feature of in-plant operations. Although drivers of industrial trucks are rarely paid on a piecework or incentive basis, they often interact with other workers who are paid on such a basis. Production workers and drivers of highway trucks whose pay depends upon the number of units produced or delivered are not reticent to remind drivers of industrial trucks of this fact. We were told that the need for industrial-truck drivers to rush tends to decrease driver attentiveness and thereby contribute to a vast number of different kinds of hazards, as well as to such operational mistakes as turning a corner too fast, and backing up while turning with the load held high.

We found in several plants that trucks and drivers are assigned to operations, but not to each other. This way of parcelling out tasks and equipment has two important consequences: (a) a single driver is often called upon to operate several makes and models of truck, and even more than one kind of truck; (b) a single truck will be operated by several different drivers over a period of time as short as one shift. These consequences in turn have implications in the broad human-factors realm. One such implication is that since different trucks have different control layouts and even identical trucks have different operating quirks and peculiarities, driver confusion is possible, especially when the driver is inexperienced or has not had a chance to learn the peculiarities of this truck before beginning his tasks with it. It can also be that where a driver has no truck that is "his" to be responsible for, he is not very careful in identifying and reporting maintenance needs of the trucks he uses. This kind of general condition can undermine the efforts of a system where preventive maintenance depends solely on the reports of defects from drivers. In addition, it is a truism in maintenance departments that the number of maintenance needs and problems on a truck multiply with the number of different people who drive it.

Although the systems-features discussed in the foregoing few paragraphs are important factors in their own right, the systems-factors that were most often thought to contribute importantly to hazards were the wage and state of maintenance of trucks, and the training of workers for tasks that involve powered industrial trucks.

We noted above that age of the truck affects its maintenance and operation adversely, and that an old, poorly maintained truck can figure in hazards of nearly every conceivable stamp. We noted in an earlier section of this chapter that maintenance crews are often overworked, understaffed, underequipped, and not always well trained. Drivers sometimes knowingly abuse their trucks, often owing to what they feel to be the demands of their own jobs. They do not always perform a thorough checkout of the truck before starting their tasks with it, possibly because of what they perceive to be their job-demands, and because they may have grounds to believe that their reports of defects will not be attended to expeditiously. Fuel is added to the fire of such a belief by shorthandedness in the maintenance department. In light of these problems, we draw the conclusion that systems of maintenance that rely solely on the drivers to inspect the trucks and detect and report defects are very rarely adequate to the task of preventing malfunctions in the trucks. A system of regularly-scheduled routine maintenance of the trucks, with thorough checklists and required documentation would seem far better. We found it quite remarkable that only one of the twelve plants we visited during the course of this study had such a system.

It was noted in an earlier section of this chapter that the vast majority of forklift drivers we talked with said they had received some training. This fact is hardly just cause for great rejoicing, however: 34% of them said they had received no training; the amount of training offered drivers seems proportional to the capacity of the truck they drive, with walkie operators generally receiving none at all; formal training is often administered as late as two years after the driver begins operating his forklift; formal training does not always include much hands-on practice, nor does it uniformly include both a written and a "road" test; it is not clear that on-the-job training is always very thorough or very intensive, or carried out in controlled circumstances with close supervision. One driver, when asked what training he had received for driving a forklift, said, "Training? In this joint? Are you kidding?"

This researcher finds shortcomings of training in other areas related to forklift operations even more glaring. We find that very few mechanics are trained specifically for repairing powered industrial trucks. If all industrial trucks were powered by gasoline or LPG, this matter would not be serious, but there are now large numbers of electric-powered industrial trucks, and there are likely to be even more as the price of liquid fuels continues to rise. Electric trucks are significantly different from the automobiles that mechanics are sometimes trained to repair.

We find also that pedestrian workers who are called upon to interact with industrial trucks are very rarely trained for these interactions; manual materials-handlers are rarely trained at all which has important consequences for the condition of the loads drivers are called upon to move; and no one receives any training emphasis in defensive walking in the plant.

This last inadequacy in training is made very poignant indeed by several considerations:

(a) the large number of cases in which a pedestrian bystander is run over or pinned by an industrial truck, or struck by part of all of a falling load; (b) the fact that, as drivers report, the attempt to avoid pedestrian can contribute to several different kinds of hazards; (c) the fact that drivers often feel pedestrians are unaware of certain crucial facts about forklift operations; (d) the fact that pedestrian traffic in an industrial plant is almost never isolated physically from industrial-truck traffic. On city streets, there is usually a curb, and a few feet distance separating pedestrians from cars and trucks. On city streets, there are also traffic lights and marked pedestrian cross-walks, and rather clear right-of-way rules. Such care in traffic engineering is almost never found within an industrial plant, and training is not offered to take its place.

The appendix to this chapter shows that there exist OSHA and ANSI safety standards that are related to most of the thirty-eight common factors identified in the course of this study. The appendix shows also that several of the factors singled out for discussion in this chapter have received a good deal of emphasis during inspections by OSHA officials, particularly training and maintenance. Even some of the operational/behavioral standards have received commendable emphasis in inspections, particularly in the case of blocking wheels on highway trucks and railroad cars, and in the case of slowing down and sounding the truck's horn at corners and intersections.

Other important items like the requirement that only safe loads be handled, are not addressed so well by either the standards or by inspections. Some additions and alterations in the standards would seem to be helpful in such areas, particularly the following: (a) it should be required that loads must be handled using the appropriate attachments or containers, which must be adequately maintained and present in adequate numbers and size near where they are needed in the plant; (b) it should perhaps be required explicitly that the plant must maintain adequate numbers of wheel blocks for highway trucks and that these be readily available where they are needed; (c) the section on platforms for elevating workers on the forks seems to stand in need of an explicit reference and inclusion of ANSI B.56.1 1975 para. 427 that deals with elevating work platforms; (d) it might be advisable to require that industrial-truck mechanics be trained specifically for repairing the kinds of trucks used in the plant, that those responsible for forming the loads that are to be moved by industrial truck be trained for these duties, that pedestrian workers who interact with industrial trucks be trained for these interactions, and that all workers in the plant be given training emphasis in defensive walking in the plant; (e) it seems appropriate to require that the plant have an adequate system of regular maintenance of the pallets and skids and stackable containers used in the plant; (f) it seems in order for certain sections stating operational/behavioral requirements aimed ultimately at the driver to be re-worded, as discussed in the section of this chapter on standards. It will be noted that the changes recommended here would require some study before they can be finalized, but no change recommended here is a very drastic one. They are all additions, clarifications, and rather minor re-wordings of sections that already exist.

But to make the standards even more workable, a great deal of further study and work would seem to be called for. In order to be quite general, the standards are necessarily rather vague on some important matters of adequacy of training, of numbers of wheel blocks and attachments, of warning devices on the trucks, of devices attachable to the truck for working at height. Employers might well have some difficulty in reckoning what they must do to come into compliance with such standards, and inspectors may well have some trepidation about judging the degree of compliance with such standards in a given plant. Accordingly, it would seem helpful to develop some guidelines for employers, and drivers as well, to give these persons a more concrete idea of what they could do to come into compliance with the spirit of the regulations. These guidelines should be of an advisory nature, not mandatory, because the specific needs can vary almost incredibly from one plant to the next, even within the same industry with roughly the same processes. It would seem to the point also to provide OSHA (and State) inspectors with techniques for judging the employer's degree of compliance on such matters of judgement as adequacy of training, of truck maintenance, of pallet maintenance, of numbers and kinds of attachments and accessories, of aisle width and storage practices, of the condition of driving surfaces and driving and walking and of safe speeds and traffic engineering in the plant. Since the workers in the plant are in the best position of anyone to judge such matters, it would seem appropriate for inspectors to have at their disposal techniques for interviewing workers on such topics and evaluating their responses. Some training for inspectors in how to use BLS accident data and plant safety records to spot potential trouble-areas would also seem in order. Clearly a great deal of study will be needed to develop such guidelines and techniques.

There is also a great deal of study that seems in order in connection with these non-design factors that contribute to industrial-truck hazards, that is not related to standards. Some of this study would be of a more scientific nature, aimed at enlarging and completing the understanding of how factors contribute to hazards; other study would be of a survey-type aimed at discovering needs and establishing approaches to the cure of The Industrial Truck Problem.

Scientific investigation is called for to learn just how factors actually contribute to hazards. The model of hazard management (see above in Chapter 2) that has guided the present study focusses attention on the individual worker and work team as the primary locus of control of the hazards of their tasks. Accordingly, a factor contributes to a hazard by making it difficult for the individual worker or the work team to control that hazard during their tasks. The present study has disclosed thirty-eight such common factors, but it has not always been able to explain just how the factors in question make it difficult for workers to excercise effective feedback-and-feedforward control of the hazards they encounter. For a properly full understanding of how factors contribute to hazards, questions like the following need to be answered for a great number of different factors: (a) Does the factor constitute a lack of information crucial to the worker's forming an appropriate control judgment? (b) Does the factor in question constitute an information-overload? Of what sort? (c) Does the factor inhibit the formation of an appropriate control-judgment, even given adequate information? How does the inhibition occur? (d) Does the factor constitute a block to the execution of an appropriate control judgment? Is the block neurological, physical, or "psychological"?

Some survey-type investigations seem in order as well, with the aim of discovering the most helpful lines of approach toward curing some of the most pressing common problems in forklift safety. We have found over the years that workers are collectively very good sources of information about what safety practices, plant layouts, operations designs, job designs, and so on tend to contribute to hazards and which do not. Since it is individual forklift drivers and pedestrian co-workers who must in the end adapt to and work with whatever curative approach is taken, it seems most appropriate to consult them in advance. Thus it seems in order to survey these workers to learn if certain kinds of hazards and factors can be eliminated and controlled best with one or another approach. For each of several kinds of accidents and hazards, and factors, workers should be asked whether changes in the loads, the physical features of the workplace, the trucks, certain job requirements, training, work rules and supervision, maintenance, or other general features of plant operations would constitute the most fruitful approach to preventing forklift safety problems. Results of such investigations can help to guide standards-setters, enforcement personnel, scientists, plant managers, training experts, manufacturers of industrial trucks, and truck-dealers to areas in which their efforts can accomplish the greatest good.

Other survey-type research can be carried out at the level of the individual plant and at the level of truck-dealer and truck-manufacturer. Plant managers would seem very well advised to survey their own workers to learn what the hazards and factors are that prevail in the individual plant. Comments from workers can be extremely helpful in setting priorities for forklift-safety efforts, and in guiding the efforts in the most fruitful directions.

Manufacturers and dealers of industrial trucks might do well to survey their users more rigorously and in much broader scope than they appear to do now. Conversations with manufacturers' representatives have left this researcher with the distinct impression that dealers and manufacturers do not have a very broad or very reliable picture of their users' real forklift-safety problems and needs. The result of this lack of wide reliable knowledge seems to be that the ingenuity of design-engineers is sometimes applied to problems that may be quite minor ones. Such a rigorous survey might yield the results that manufacturers and dealers should devote efforts toward fitting better-vision masts and more comfortable seats and better foot-padding and more durable markings to the more widely used models of older trucks; such a survey could show that design-priorities for new trucks should center around matters like eliminating pinchpoints around the mast rather than the shape of hand-grips for trucks designed to be steered with one hand; such a survey might show that manufacturers and dealers should allow design-innovations to take a back seat to efforts in referring users to consultants with expertise in other areas of truck operations - e.g. training, plant layout, load formation, materials flow, traffic engineering, maintenance of trucks and physical plant, housecleaning and the like.

AND TO CAP IT ALL OFF...

Five crucial matters have become quite clear in the course of the present study: (a) the factors that contribute to industrial-truck hazards and accidents are myriad in number and kind, and they interact with each other and with factors that are otherwise quite innocuous in a fairly bewildering number of different ways; (b) the conditions in the plant that give rise to hazard-making factors for forklift operations vary almost incredibly from one plant to the next even among plants in the same industry and with roughly similar industrial processes; (c) the effective and safe performance of materials-handling tasks using powered industrial trucks depends very much on the way that persons other than the driver and his helper(s) perform tasks that are distinct from, but obviously related to the tasks of the driver and his helper(s);

the driver and his helpers typically have little or no influence over the way in which these other tasks are carried out; (d) the training that workers involved in industrial-truck operations receive generally tends to leave somewhat to be desired; (e) the vast majority of powered industrial trucks in use today are quite old, and there is thus a large time-lag between the state of the art available in new-truck designs that can be purchased or leased and the trucks that drivers and pedestrian workers are called upon to cope with in their everyday tasks.

These five matters have drastic consequences for safety research, for standards-setting and -enforcement, and for direct accident-prevention efforts.

1. No single factor or group of factors can be said to have over-bearing importance in the causation of forklift accidents and in the prevention of same. When the complex interactions of factors and the plant-to-plant variations are taken adequately into account, it can turn out that no one factor or group of factors even rises to the status of statistical significance.

2. The ergonomic design (or lack thereof) cannot justly be said to be among the top three, top five, or even top ten considerations in the causation and prevention of industrial-truck-safety problems. That is not to way that human-factors design of trucks is not important and cannot be improved - what is said in this chapter would surely vitiate that conclusion. But its importance cannot be given a precise ranking of any sort.

3. The same is true for truck-design inadequacies in general as is true for ergonomic design of powered industrial trucks.

4. Hazard-making factors can arise or be eliminated within every task-element related even remotely to industrial-truck operations, from truck design to truck selection and procurement to load formation to housekeeping to plant layout to training to operating with the truck to job-design to operations-design and materials-flow, and so on ad nauseam. A decision or change in any one of these elements can have drastic consequences, be rendered ineffectual, or be controlled for in at least one other element. A management decision to place production workers on a piecework or incentive basis of pay can give rise to some very ugly industrial-truck hazards, even when industrial-truck drivers themselves are not paid on this basis. The incorporation of an inch-pound load-moment device can be rendered ineffectual by poor maintenance or uninformed mechanics; it can be a source of great frustration to a highly-skilled driver if he is never told that his truck is equipped with such a device. A more stable truck can be rendered irrelevant if the driver goes around a corner at near top speed with a heavy load held high. A cramped, poorly padded driver facility of the truck can be compensated for by a driver who knows how to take frequent stretch-and-limber-up breaks without letting his foreman catch him at it.

5. Therefore, concentration of research and direct accident-prevention efforts in a narrow range of areas for universal application, such as a national-emphasis-effort on training and/or truck design alone, is not likely to accomplish much toward the reduction in frequency and severity of forklift accidents.

6. Industrial-truck operations should be regarded as single nationwide system, of which every driver, every pedestrian co-worker, every manual materials-handler, every truck designer and assembler and dealer and saleman, every manager and purchasing agent and industrial planner, every safety researcher and data-gatherer and standards-developer and enforcement-officer should consider himself a part. As things stand now, each of the elements of this system performs inadequately at least sometimes, and the system as a whole seems very poorly integrated. No one element is always properly aware of the needs of the other elements.

7. To allow better integration of the industrial-truck-operations system, pedestrian workers and forklift drivers should be made better aware of each others' job-requirements and equipment-limitations; plant managers should become more aware of the actual hazards faced by their workers, and the factors that contribute to these hazards; dealers and manufacturers of industrial trucks could be better informed about the actual forklift-safety problems of their users, and could apparently do better at communicating their own expertise to the users and drivers; inspectors should be equipped with some good techniques for identifying important safety problems in forklift operations in the plant at hand, tracing them to their roots, and verifying their importance in the plant.

The human factors involved in industrial-truck hazards and accidents include the ergonomic design of these trucks, but they consist more importantly in the way in which persons other than the industrial-truck driver and his helper (s), and these persons as well, perform tasks related to handling materials with powered industrial trucks. The most remarkable areas of human performance would appear to be these: establishing and maintaining effective communication among workers sharing the same material-handling task or the same aisle-space; the decision to have a co-worker ride on the truck, the load, the bare forks, or an empty pallet; the performance of those responsible for forming the loads to be carried by industrial trucks; the performance of those responsible for blocking and bed-surfaces; the performance of those responsible for planning plant layout, storage practices, material flow, traffic engineering, training, pa-bases and production schedules, and procurement of trucks and attachments and accessories; the performance of those responsible for maintaining the trucks, and for housecleaning; the performance of those persons responsible for the design of the trucks themselves; and the integration of the industrial-truck-operations system as a whole.

A BRIEF BIBLIOGRAPHY

Anonymous "Industrial Trucks: An IE Special Report," Industrial Engineering, September 1975, pp. 19-37.

Anonymous "Operator Training--OSHA's Hidden Failure, How You Can Correct It," Modern Materials Handling, October 1975, pp. 45-60.

Anonymous "Powered Hand Trucks," National Safety News, April 1975, pp. 67-70.

Anonymous "NSC's Industrial Department Offers Lift Truck Safety Training Program," National Safety News, July 1975, pp. 49-52.

Anonymous "Industrial Truck Accidents Surveyed," National Safety News, April 1971, pp. 41-50.

Anonymous "Why You Should Take Another Look At Lift Truck Cabs," Modern Materials Handling, January 1977, pp. 66-69.

Anonymous "OSHA and Materials Handling--The First 2 Years," Modern Materials Handling, April 1973, pp. 40-43.

Anonymous "Inch Pound Controls: Most Stable Lift Trucks Yet!" Modern Materials Handling, April 1974, pp. 52-55.

ANSI B.56.1 1969 American Society of Mechanical Engineers

ANSI B.56.1 1975 Amercian Society of Mechanical Engineers

Campbell, Charles E. "Total Responsibility--An Industrial Forklift Operator's Improvement Program," National Safety News, April 1975, pp. 67-70.

Coleman, Patrick J. & Smith, Karl U. "Hazard Management: Preventive Approaches to Industrial Injuries and Illnesses," Research Report, Wisconsin Department of Industry, Labor and Human Relations, 1976.

Commerce Clearing House Products Liability Reporter, Para. 5147, 5333, 7399, 7026, 7687, 6925, 7843, 7795, 7610, 7547.

Drury, C. G. and Dawson, P. "Human Factors Limitations in Forklift Truck Performance," Ergonomics, vol. 17 #4, 1974, pp. 447-456.

Gottlieb, Mark S. "Worker's Awareness of Industrial Hazards," Research Report, Wisconsin Department of Industry, Labor and Human Relations, 1976.

Hanson, Jan-Erik. "Factors Affecting Vehicle Control" prepared for presentation to 1975 winter meeting of American Society of Agricultural Engineers, December, 1975.

Hart, Joseph W. "At Last--A Meaningful Study of Industrial Truck Accidents," Modern Materials Handling, July, 1976, pp. 44-45.

Laumann, Hans J. "Unfälle Mit Flurförderzeugen," Die Berufsgenossenschaft, March, 1977, pp. 102-106.

Lovested, Gary E. "Top Ten Forklift Truck Accidents," prepared for presentation at National Safety Congress, October, 1976.

McPeek, John S. "Summary Analysis of Powered Industrial Truck Accidents," Research Report, Wisconsin Department of Industry, Labor and Human Relations, 1976.

29 CFR 1910.178 Revised January, 1976.

Smith, Karl U. "Performance Safety Codes and Standards for Industry: The Cybernetic Basis of the Systems Approach to Accident Prevention" in Widner, Joanne T. (ed.) Selected Readings in Safety. Academy Press, Macon, Georgia, 1973.

Various paid advertisements in Modern Materials Handling, esp. August, 1977, p. 112; February, 1977, p. 102; January, 1977, p. 70.

APPENDIX TO CHAPTER 4

Table of Factors and Standards and Violations

Factor	Standard	1975 Violations*
A. SYSTEMS - FEATURES OF INDUSTRIAL-TRUCK OPERATIONS IN PLANTS		
1. Training	a. 178(L) provides that only authorized and trained persons shall operate industrial trucks	a. 610 $8,502 fines
	b. 178(Q)(1) all repairs shall be made by authorized personnel	b. N.A.
2. Production-Speed Stress		
3. Assignment of Trucks & Drivers to Each Other		
4. Availability of Tools & Attachments & Accessories	a. 178(G)(4) a conveyor or overhead hoist or equivalent material handling equipment shall be provided for handling batteries	a. 1 $0 fine
	b. 178(K)(2) requires wheel-stops to be provided for railroad cars	b. 86 $2,115 fines
	c. 178(K)(1) requires setting brakes, blocking rear wheels of semi-trailers	c. 207 $2,640 fines
	d. 178(M)(12) sets design requirements for trucks equipped with controls elevatable with the carriage or forks for lifting personnel	d. 142 $13,500 fines
	e. ANSI B.56.1 1975 para. 427 on elevating platforms	e. --

5. Maintenance of Trucks	a. 178(P)(1) defective trucks shall be removed from service until restored to safe operating condition	a. 930 $16,149 fines
	b. 178(Q)(1) defective trucks shall be removed from service	b. 291 $3,805 fines
	c. 178(Q)(7) trucks shall be examined daily or at end of each shift. Defects found shall be reported immediately and corrected; defective trucks shall not be placed in service	c. 336 $4,321 fines
	d. ANSI B.56.1 1969 para 702A A scheduled preventive maintenance, lubrication, and inspection system shall be followed	d. --
6. Pay-Scales and Job-Prestige Levels		
7. Age of Trucks	as under Maintenance, above	

B. OPERATIONAL/BEHAVIORAL REQUIREMENTS OF TASKS

1. Backing Up	a. 178(N)(4) driver shall travel with load trailing if load being carried obstructs forward view	a. 635 $5,635 fines
	b. 178(N)(6) driver shall look in direction of travel and keep a clear view of path of travel	b. 9 $275 fine
2. Turning	a. 178(N)(4) (See above)	a. See above
	b. 178(N)(15) while negotiating turns, keep speed down to a safe level by means of turning the hand steering wheel in a smooth sweeping motion. Except when maneuvering at a very low speed, the hand steering wheel shall be turned at a moderate, even rate	b. 1 $0 fines

3. Warning Others of Truck's Presence	a. ANSI B.56.1 1969 para 427 requires horn, or whistle, or gong or other warning device	a. N.A.
	b. 178(N)(4) driver shall slow down and sound the horn at cross aisles and other locations where vision is obstructed	b. See above
4. Requesting/Giving Rides on the Truck, Load, Bare Forks or Empty Pallet	a. 178(M)(3) unauthorized personnel shall not be permitted to ride on powered industrial trucks. A safe place to ride shall be provided where riding of trucks is authorized	a. 78 $6,450 fines
	b. 178(M)(4) employer shall prohibit arms or legs from being placed between the uprights of the mast or outside the running lines of the truck	b. 38 $360 fines
	c. 178(M)(12) (See above)	c. See above
	d. 178(O)(1) only stable or safely arranged loads shall be handled	d. 24 $610 fines
	e. 178(O)(2) only loads within the rated capacity of the truck shall be handled	e. 13 $220 fines
	f. ANSI B.56.1 1975 para 427 on elevating platforms	f. --
5. Walking and Working in the General Area of Life-Truck Operations	a. 176(A) and 22(B)(1) permanent aisles and passageways shall be kept clear and in good repair, with no obstruction across or in aisles that could create a hazard	a. Fourth most frequent violation 1973**
	b. 22(B)(2) permanent aisles and passageways shall be appropriately marked	b. N.A.
6. Communication during Shared Tasks, or in Shared Spaces	a. 178(N)(4) (See above)	a. See above
	b. 178(N)(6) (See above)	b. See above
	c. 178(N)(8) speed must allow safe stopping	c. 13 $265 fines

7. Parking the Truck	a. 178(M)(5) specifies procedure when driver leaves the truck	a. 516 $4,105 fines
8. Blocking Wheels on Semi-Trailers and Railroad Cars, Checking on Blocking and Bed-Surfaces	a. 178(K)(1) (See above)	a. See above
	b. 178(K)(2) (See above)	b. See above
	c. 178(K)(3) requires fixed jacks under semi-trailer when tractor is unhitched	c. 3 $85 fines
	d. 178(K)(4) requires positive prevention to be provided against railroad car moving when dockplates are in place	d. 5 $30 fines
	e. 178(M)(7) repeats the provisions of (K), mandates checking bed-surfaces on trucks, trailers, railroad cars before driving industrial trucks onto them	e. 101 $1,115 fines
9. Non-Required Behaviors-Horseplay, Showoff Driving, Jerky Driving	a. 178(N)(9) stunt driving and horseplay shall be prohibited	a. 3 $65 fines
10. Generally Attentive Operating		
11. Servicing the Trucks	a. 178(G)(2) facilities shall be provided for flushing and neutralizing spilled electrolyte	a. 297 $2,530 fines
	b. 178(G)(4) (See above)	b. See above
	c. 178(Q)(7) (See above)	c. See above
	d. 178(Q)(1) (See above)	d. See above
	e. 178(P)(1) (See above)	e. See above
	f. 178(Q)(4) trucks in need of repairs to the electrical system shall have battery disconnected prior to such repairs	f. 0 $0 fines

C. OBSERVABLE CHARACTERISTICS OF THE TASK-SITE

1. Narrow Aisles	a. 176(A) and 22(B)(1) sufficient safe clearances shall be allowed for aisles	a. See above

2. Crowded, Cluttered Aisles	a. 176(A) and 22(B)(1) (See above and below)	a. See above
3. Intersections and Doors	a. 178(N)(3) no passing at intersections or blind spots	a. 0 $0 fines
	b. 178(N)(4) (See above)	b. See above
	c. 178(N)(6) (See above)	c. See above
	d. 178(N)(8) (See above)	d. See above
	e. 178(N)(10) slow down for wet and slippery floors	e. 0 $0 fines
	f. 178(N)(14) avoid hitting loose objects on the driving surface	f. 2 $60 fines
	g. 176(A) and 22(B)(1) (See above)	g. See above
4. Concentrations of Traffic		
5. Condition of the Driving Surface	a. 176(A) and 22(B)(1) (See above)	a. See above
	b. 22(A)(1) all places of employment - shall be kept clean and orderly and in a sanitary condition	b. N.A.
	c. 22(A)(2) the floor of every workroom shall be maintained in a clean and, so far as possible, a dry condition	c. N.A.
	d. 178(N)(1) observe all traffic regulations, maintain distance about two truck lengths from truck ahead. Keep truck under control at all times	d. 10 $335 fines
	e. 178(N)(10) (See above)	e. See above
	f. 178(N)(14) (See above)	f. See above
6. Noise, Obnoxious Odors, Toxic Gases, Dust, Lighting	a. 178(I)(1) sets TLV for CO, refers to 1000	a. 5 $60 fines
	b. 178(H)(1) sets standards for lighting intensity	b. 11 $100 fines

6. Noise (Cont'd.)	c. 178(H)(2) mandates auxiliary lights for trucks operating in dark areas.	c. 8 $60 fines
	d. 178(G)(2) (See above)	d. See above

D. LOAD CHARACTERISTICS

1. Poor Palletizing	a. 178(O)(1) (See above)	a. See above
2. Pallets in Poor Repair	a. 178(O)(1) (See above)	a. See above
3. Load is Too Heavy	a. 178(O)(1) (See above)	a. See above
	b. 178(O)(2) (See above)	b. See above
	c. 178(O)(3) long or high loads that affect capacity shall be adjusted	c. 0 $0 fines
4. Load is Inherently Unstable or Blocks Vision	a. 178(O)(1) (See above)	a. See above
	b. 178(O)(2) (See above)	b. See above
	c. 178(O)(3) (See above)	c. See above
	d. 178(O)(4) when using attachments, secure and handle loads carefully	d. 1 $0 fines
	e. 178(O)(5) driver shall get forks as far under load as possible	e. 2 $80 fines

E. TRUCK FEATURES

1. Brakes	a. ANSI B.56.1 1969 para 410 thru 416 set minimum drawbar-drag figures, maximum pedal pressures	a. N.A.
	b. 178(P)(1) (See above)	b. See above
	c. 178(Q)(1) (See above)	c. See above
	d. 178(Q)(7) (See above)	d. See above
2. Steering	a. 178(P)(1) (See above)	a. See above
	b. 178(Q)(1) (See above)	b. See above

2. Steering (Cont'd.)	c. 178(Q)(7) (See above)	c. See above
3. Malfunction of Clutch, Shift Linkage or Transmission	a. 178(P)(1) (See above)	a. See above
	b. 178(Q)(1) (See above)	b. See above
	c. 178(Q)(7) (See above)	c. See above
	d. 178(M)(5) (See above)	d. See above
4. Malfunction of Speed- and Direction-Switches	a. 178(P)(1) (See above)	a. See above
	b. 178(Q)(1) (See above)	b. See above
	c. 178(Q)(7) (See above)	c. See above
5. Leaks in Hydraulic Systems, and/or Transmissions	a. 178(P)(1) (See above)	a. See above
	b. 178(Q)(1) (See above)	b. See above
	c. 178(Q)(7) (See above)	c. See above
6. Driver Vision	a. 178(Q)(9) trucks that overheat must be removed from service, defect remedied before placing back into service	a. 1 Fines N.A.
7. Ergonomic Design Features	a. ANSI B.56.1 1969 para 421 overhead guard must be minimum 74" from top of platform to underside of canopy on standup rider trucks	a. N.A.
8. Safety Devices Lacking, Inadequate, or Malfunction	a. ANSI B.56.1 1969 para 421 sets specifications for overhead guards	a. N.A.
	b. B.56.1 1969 para 422 sets specifications for load backrest extensions	b. N.A.
	c. 178(E)(2) and (M)(10) require use of load backrest extension if type of load presents hazard of its falling backward. Extension must conform to ANSI B.56.1 1969	c. 60 $1,520 fines
	d. 178(E)(1) and (M)(9) require overhead canopies	d. 522 $14,865 fines

8. Safety Devices (Cont'd.)	e. B.56.1 1969 para 427 (See above)	e. N.A.
	f. 178(P)(1) (See above)	f. See above
	g. 178(Q)(1) (See above)	g. See above
	h. 178(Q)(7) (See above)	h. See above
9. Emissions from Truck	a. 178(I)(1) (See above)	a. See above
10. Driver Confusion about Controls	a. ANSI B.56.1 1969 para 411 thru 416 set general guidelines for control layouts and modes of operation	a. N.A.
	b. 178(A)(1) nameplates must be kept in good legible condition	b. 178 $6,695 fines
	c. 178(Q)(10) trucks must be kept clean	c. 35 $35 fines

* 1975 violation data courtesy of OSHA
** from Anonymous, 1973

CHAPTER 5. HUMAN FACTORS IN USING CRANES AND HOISTS FOR OVERHEAD LIFTING

I. INTRODUCTION

The use of cranes and hoists for overhead lifting and materials handling is pervasive throughout industry. Crane and hoist systems allow industrial operations great flexibility in moving and manipulating objects from a few pounds to 300 or more tons. Besides this flexibility, cranes and hoists occupy little usable floor area while providing a tremendously productive tool to numerous manufacturing operations. In construction, cranes of various types are indispensable. Warehousing, shipping, maintenance and repair operations find various crane or hoist systems invaluable.

However, as with any mechanical technology, the use of overhead lifting devices presents particular hazards to the humans who must operate and interact with these machines. This chapter will attempt to define these areas of hazards in the use of hoists and cranes; indicate what is being done to control these hazards; and suggest what might be done to provide improved and realistic accident prevention and worker protection through the control of crane- and hoist-related hazards. Throughout this effort, comments on the ergonomic relationship of human behavior to machine function will be employed to indicate the interactive and multi-factored nature of crane and hoist operations.

OVERVIEW OF CRANE AND HOIST OPERATIONS

Understanding the safe operation of any crane or hoist, whether a 200-pound garage hoist or a 400-ton construction ringer crane, involves understanding the system in which that crane or hoist functions. That system involves the physical dimensions of the crane or hoist (controls, capacity, slings and attachments, etc.); the behavioral components of crane or hoist use (operator selection, proper procedures, hitcher operator communications, etc.); and the interaction of these two factors (equipment selection, maintenance reporting and schedules, sling inspection and repair, etc.). When crucial components of any system fail to integrate properly, variance develops in the system. This variance in the system's operation must be compensated for or the possibility of system failure exists. This study report seeks to indicate what obstacles to the proper integration of crane or hoist operations are likely to occur, and how these unwanted situations can be prevented; or should they occur, how can workers be protected from injury.

Simply, the function of any crane or hoist involves three steps: lifting some object to a height adequate to clear surrounding obstructions; moving the object to some desired location within the range of the crane or hoist's design, and the placement of the object at some desired position. Within this process, the crane or hoist can be used to manipulate or support the object so that some further operation involving the object might be carried out. One other element crucial to successfully moving any object with a crane or hoist involves properly attaching the object to be moved to the crane so that the object will not fall as it is handled and moved.

Although cranes and hoists come in a variety of sizes and designs, variations of the above steps are common to the operations of each machine's use. However, because of differences in their design, location, size or type of locations, different types of cranes and hoists have various hazards involved in their operations to a greater or lesser degree.

These variations in use and scope of operations segment cranes and hoists into four general categories: Mobile cranes and tower cranes which are designed to be moved from one job location to another, used extensively in construction and outdoor operations; hoists and small cranes fixed in position or mounted on a single travel rail which may swing around a fixed pivot or be stationary; cranes and hoisting systems operated by some portable remote station, where the crane or hoist has travel in two dimensions other than hoisting (bridge and gantry type cranes--radio or pendant operated); and cranes and hoisting systems operated from a cab attached to the crane or some fixed remote station, where the crane or hoist has travel in two dimensions other than hoisting (bridge and gantry cranes, stacker cranes, and custom rail guided cranes). While this division is not perfect, and some cranes exhibit components of more than one category, this categorization of equipment does generate issues unique to the use of cranes in each of these divisions. These issues will be discussed at length in Section III of this chapter.

MAJOR HAZARDS INVOLVED IN CRANE USE

The principal hazards involved in overhead lifting are similar to the hazards involved in aircraft flight. In both cases the main goal is to lift an object (aircraft or materials load), transport it and set it down at a chosen location. Failure in the suspension mechanisms of aircraft mean a crash or emergency landing; a failure in the suspension of a lifted crane will result in the load's falling. When an aircraft in flight strikes some intermediate object, like a mountain, its flight is terminated; when a crane load strikes a pedestrian or a machine while being moved, damage is done and a load could fall. A poorly maintained aircraft is likely to operate roughly and unreliably; a crane or hoist poorly maintained can operate jerkily, respond to controls indifferently, and occasionally fail physically far below its rated capacity.

This analogy can be extended; however, the important point is that the obvious hazards to safe aircraft transportation have been controlled by developing elaborate systems to manage these inherent hazards. When the visibility of an aircraft pilot is limited or restricted, flights are not allowed unless instrumentation to compensate for this limitation is used; if aircraft do not receive periodic maintenance checks or adhere to inspection standards they aren't allowed to fly; and pilots who lack the training, experience, or physical ability to safely operate various types of aircraft are restricted to only those types of aircraft for which they qualify.

Similar types of hazard management in the use of crane and hoist systems are either nonexistent, or where these sorts of controls or restrictions are imposed through standards or individual company policy, their implementation is often compromised by expediency or "get the job done" considerations.

In the balance of this report, the nature of hazards and their possible controls in crane and hoist use will be documented and discussed. By utilizing accident reports and investigations; results of interviews with overhead lifting equipment manufacturers and distributors; interviews with managers, engineers and workers in industries using crane and hoist systems; and appropriate allied information sources (other research, conference comments, published articles, etc.), an attempt will be made to define the dynamic interaction of factors which are involved in crane and hoist operations safety. Where appropriate, examples from this data will be used to illustrate various aspects of safety in crane and hoist use. These examples are not intended to limit the scope of applicability of this report's results; rather, they are intended to stimulate the users of this report to translate it's results to the specific crane or hoist use situation they are concerned with.

REPORT ORGANIZATION

The following section of this chapter details the process of data gathering and field observations forming the methodology for studying crane and hoist use. The next section will summarize the results of the data analysis and field observations performed concerning the safe use hazards and human factors issues in crane and hoist use. Following the presentation of this data, Section IV discusses the implications of this data to human factors in crane and hoist use. The final section presents some recommendations for further safety efforts related to crane and hoist use.

II. CRANE AND HOIST STUDY METHODOLOGY

As is indicated in Chapter 3, the methodology in this project involved three phases: (1) the gathering and analysis of causal accident information; (2) the observation of field use of materials handling equipment, integrating the accident information into these field investigations; and (3) the analysis of this information for the formulation of research conclusions. Below we will briefly indicate how these procedures were applied to the study of human factors in the safe use of cranes and hoists.

DATA ANALYSIS FOR CAUSAL PATTERNS

The qualitative and quantitative description of crane and hoist accidents detailed in Section III of this chapter are the results of studying crane and hoist accident data from the Wisconsin Worker's Compensation System. This data consists of causal comments and causal data coding from employer's reports of compensable accidents, employe causal remarks on an accident benefits assessment questionnaires, and field inspection reports of selected accidents.

This data analysis generated categories of accident description and indicated causal factors involved in these crane and hoist accidents. Information obtained from the data analysis was used to generate a Detailed Analysis of Crane and Hoist Accidents summarizing the significant information involved in the data analysis, and documenting the descriptive data factors involved in the accident categories. This accident analysis was used to direct the efforts of the next phase of the study, the observation and assessment of human factors and safety hazards in the use of cranes and hoists.

OBSERVATIONS AND SITE VISITS

Ten industrial establishments were visited in the course of this study to observe and discuss the use or design of cranes and hoists. Three of the establishments were primarily approached as manufacturers or suppliers of cranes or hoists and overhead lifting attachments. One manufacturer is a large Wisconsin corporation which is the major domestic manufacturer of large Overhead Bridge cranes and a major manufacturer of electric hoists for incorporation into small and medium sized crane and hoist systems, as well as other heavy equipment and mobile hydraulic cranes. A second Wisconsin manufacterer specialized in the design and production of large lift, ringer and tower mobile cranes; this corporation has earned a reputation for excellence in this field. The third establishment was a small energetic company engaged in the supply and fabrication of slings and attachments for overhead lifting, as well as the sale of small electric hoist systems. This company was the main supplier of chain and other sling accessories to a number of large and small establishments participating in our study.

Of the seven other companies visited to observe crane or hoist operations, four involved foundry operations exclusively or had a foundry operation as part of their manufacturing operations. Those establishments with foundry operations as part of their manufacturing plant were involved in the production of plumbing fixtures and small gasoline engines: papermaking machinery; and large drive gears and transmissions for maritime and other large scale applications. The three remaining establishments were an aluminum rolling mill, attached to a large aluminum stamping corporation; a construction site involving the erection of a large electrical generating plant; and a transfer, storage and crane rental operation.

The extent of the observations and discussions carried on in each establishment visited varied and was usually determined by the willingness of the company involved to allow the researchers to approach workers on the shop floor; or the time and physical energy limitations of the researchers and accompanying company representatives. In five of the establishments visited, members of our research team were able to directly talk with workers on the shop floor, when such conversations did not upset production. In these instances, workers were asked questions designed to extract the workers' knowledge of crane-or hoist-use hazards or hazard controls. In plants or work sites where it was not feasible to interview some or all workers, supervisory and management personnel were made available for extended discussions. These types of discussions were also carried out in plants where workers were interviewed.

Where it was allowed, a photographic record was made of crane and hoist operations and indicated hazards. These 35mm transparencies were used by researchers in subsequent discussions of the hazards and hazard control systems observed in the establishments visited.

OTHER SOURCES OF DATA AND INFORMATION

In addition to the data analysis discussed above and the field observations of equipment used, other avenues of information related to the safety of crane and hoist operations were pursued. The lack of a vast body of literature in ergonomic and engineering journals was indicated by an initial manual search of these sources and later confirmed by a computer literature search (University of Wisconsin Engineering Library Services). Trade journals, while found to contain information of probable value to industrial managers concerned with efficient hoisting equipment selection or standards compliance, seldom contained articles providing data on the causes of safety problems in materials handling equipment use. Those articles which were found to be of value will be discussed at appropriate times in this report and are listed in the bibliography at the end of this chapter.

One notable source of information on mobile crane safety and proper operations was obtained through discussions with Mr. Don Dickie of the Province of Ontario's Construction Safety Association. Mr. Dickie's organization, as part of the Province's Worker's Compensation program, carried out an in-depth study of crane use accidents in construction. The application of their research results through training and certification aimed at crane operators has had a significant effect on reducing Ontario's crane accidents in construction. This program and two training books on crane operation and rigging published by the Construction Safety Association of Ontario are discussed in greater detail in Section IV of this chapter.

An additional source of information on mobile crane operations was obtained when three members of our research team attended a course on crane failures presented by the University of Wisconsin Extension. Information and comments gathered from this course will be presented in the mobile crane section of a supplementary report (Gottlieb 1978).

HAZARD ANALYSIS AND DATA INTEGRATION

Having amassed a large amount of accident data, information sources, and interview notes related to crane and hoist use generated through this project, the final task involved synthesizing a coherent picture of the human factors involved in the safe operations of cranes and hoists. This process involved two basic components of analysis and a final component of expanding on the findings of the study to formulate suggestions for improving efforts at eliminating the losses accrued from crane and hoist related accidents.

The first analysis effort involved the integration of causal and descriptive accident data with the results of field observations and interviews related to crane and hoist use and their hazards and hazard control systems. This consisted of analyzing the results of field observations and interviews to relate the hazards or hazard controls indicated in this data to five categories, indicating where in the industrial work process the hazards or controls originated or where realized. These categories (remote preoccupational conditions, at site preoperational conditions, at site task operations, at site task follow-up, and overall operation support), described in the Chapter 2, are intended to indicate where in the industrial process attention might best be directed to reduce a hazard's developing into an accident. The results of this analysis are presented in Section III.

The second analysis involved the incorporation of comments gathered from field observations and interviews on crane and hoist hazards into the general accident categories developed in the initial analysis of crane and hoist accidents. Hazards were listed under each category of accident type for which the hazard seemed appropriate. The central themes of these hazards were indicated and used to summarize the nature of the hazards which were found to be appropriate to each category of accidents. The results of this summary and analysis are contained in the next section of this chapter.

The final effort of the study, whose results are presented in Sections IV and V of the chapter, involved the application of the data and results of this project to specific hazard management and control situations involving cranes and hoists. In Section IV, areas of human factors problems determined to be crucial by the researchers and consultants in this project are addressed. Section V is a more subjective attempt to outline suggested actions which may be initiated by industry or government to reduce the undesired effects of crane and hoist hazards.

III. ACCIDENT AND FIELD INTERVIEW ANALYSIS--HAZARDS AND CONTROLS RELATED TO THE CAUSATION OF CRANE AND HOIST ACCIDENTS

ACCIDENTS, HAZARDS AND HAZARD CONTROL

The ambition of this section is to condense a large amount of accident data and interview and observation notes involving crane and hoist use in industry. This data documents the causal nature of accidents which can and do arise out of these machines' use. The procedure used to generate this data provides the structure for reporting the results of its' analysis. First, a category of crane and hoist accidents will be defined. The hazards related to this type of accident, or to control systems suggested or used to control hazards indicated by workers, managers or researchers' observations will be discussed.

This study incorporated a philosophy developed by K.U. Smith (Smith, 1975; Coleman and Smith, 1976) which states that accident control in industry can only be achieved by the management of hazards which exist in industrial processes, which when not compensated for, can eventaully produce an accident. The realization of this philosphy of Hazard Management dictates an approach to the promotion of safety and health in the workplace by first, defining the hazard dynamics of an accident prone situation (Swain, 1974); and then developing controls and standards for equipment and performance to avoid the accident protential of a hazard (e.g. maintenance of a chemical exposure TLV (Stellman, 1977) or avoidance of equipment failure. The bulk of this section will present a hazard analysis of crane and hoist accidents, and point toward directions for the control of these hazards.

Hazard controls related to the use of crane and hoist systems are either involved in the prevention of a hazard's realization or the protection from injury occurrence should a hazard be realized. While prevention of the development of a problem is desirable as a control for that problem, protective measures are necessary if preventive measures fail to control or avoid the development of a problem. This dichotomy of prevention and protection will be included in our discussions of crane or hoist use hazards.

ACCIDENT DATA ANALYSIS SUMMARY

The sources of accident data--the Wisconsin Worker's Compensation Case History file, Employe comments from the 1974 Promptness of Payment Survey, and investigation of accident reports are explained in detail in the methodology overview of this report and in Chapter 3. It was found that the information contained in the W.C. Case History file was not of sufficient detail to generate concise categories of crane and hoist accidents of any value in defining causal factors in these accidents. The 413 employe responses on the promptness survey and the 76 accident investigations which were found to relate to crane and hoist use were of sufficient detail to generate causal categories.

Table 5-1 indicates the 27 causal categories of crane or hoist accidents generated from the two above mentioned data sources. These categories were

TABLE 5-1
CRANE AND HOIST ACCIDENT ANALYSIS CATEGORIES

Type #1	Category Description	Employe Reports[1] Freq.	Percent	Accident Investigations[2] Freq.	Percent	Fatals	Cited
1.	Loads being lifted which slip from hooks, chains, slings, etc. to injure workers	97 cases	23.5%	12 cases	15.7%	2	3
2.	Workers struck by loads being moved or by parts of crane or hoist, while machine is moving.	36 "	8.7%	5 "	6.5%	1	1
3.	Loads or parts of load hook up falling from crane or hoist to injure due to breakage of hooks, cables, chains, etc.	25 "	6%	9 "	11.7%	-	5
4.	Workers injured by being caught between lifted loads lifted and/or hook up elements of hoist or crane.	37 "	9%	2 "	2.7%	-	-
5.	Crane or hoist or integral part of crane or hoist (boom, anchor hardware, etc.) falling and causing injury.	30 "	7.3%	5 "	6.5%	1	3
6.	Slippage in the lift mechanism of the crane or hoist which causes the load to fall or machine to jerk and cause injury.	20 "	4.7%	5 "	6.5%	1	2
7.	Worker injured falling or stepping off crane or hoist.	18 "	4.3%	2 "	2.7%	-	1
8.	Worker injured falling from overhead crane rail.	2 "	.5%	-	-	-	-
9.	Overexertion in operation (moving loads) of crane or hoist.	18 "	4.3%	-	-	-	-

TABLE 5-1 continued

CRANE AND HOIST ACCIDENT ANALYSIS CATEGORIES

Type #1	Category Description	Employe Reports[1] Freq.	Employe Reports[1] Percent	Accident Investigations[2] Freq.	Accident Investigations[2] Percent	Fatals	Cited
10.	Loads or parts of cranes or hoists hitting other objects while moving and falling or causing something else to strike injured.	16 cases	3.7%	4 cases	5.3%	-	1
11.	Injured pinned between moved load and other object.	15 "	3.7%	1 "	1.3%	-	-
12.	Workers getting caught in mechanical part of hoist mechanism.	14 "	3.5%	4 "	5.3%	-	4
13.	Loads falling from cranes or hoists, not specifiable.	12 "	3%	-	-	-	-
14.	Operator of crane or hoist injured by object not part of crane or hoist while operating (tripping or falling over object).	10 "	2.5%	1 "	1.3%	-	-
15.	Workers injured setting up or disassembling a crane or hoist.	8 "	2%	3 "	4%	1	2
16.	Load or part of hoist lowered on injured.	8 "	2%	-	-	-	-
17.	Overhead and other cranes running into injured.	7 "	1.7%	5 "	6.5%	-	3
18.	Injured while manuvering materials to load on crane or hoist.	7 "	1.7%	-	-	-	-
19.	Injured while replacing cable on crane or hoist (mainly falls).	6 "	1.5%	-	-	-	-

TABLE 5-1 continued

CRANE AND HOIST ACCIDENT ANALYSIS CATEGORIES

Type #1	Category Description	Employe Reports[1] Freq.	Employe Reports[1] Percent	Accident Investigations[2] Freq.	Accident Investigations[2] Percent	Accident Investigations[2] Fatals	Cited
20.	Bumping into stationary crane or hoist to injure self.	4 cases	1%	-	-	-	-
21.	Worker injured climbing into crane	4 "	1%	1 case	1.3%	-	-
22.	Worker pinned between piles of material while hooking them.	4 "	1%	-	-	-	-
23.	Contact with electricity through crane.	3 "	.7%	17 cases	23.3%	11	9
24.	Crane or hoist mishooking and tipping load to cause injury.	2 "	.5%	-	-	-	-
25.	Ergonomics in crane design (of cab and controls).	2 "	.5%	-	-	-	-
26.	Crane operators injured by collision	2 "	.5%	-	-	-	-
27.	Cranes and hoists not determinable.	10 "	2.5%	-	-	-	-
TOTALS		413 cases		76 cases		17	34

1 Employe reports are taken from comments returned on a questionnaire sent out to nonfatal victims of reported worker's compensation cases in 1974. The primary purpose of the questionnaire was to evaluate the promptness of benefit payments. The question asked of these workers which was used for the above analysis was: Describe below what caused your injury or illness. Name the object, machine, material, condition or action which caused it to happen. All reports which indicated the involvement of cranes or hoists were included in this analysis.

2 Accident investigations analyzed in this section were carried out by investigators from the Wisconsin Division of Safety and Buildings between 1971 and 1975. The determination of accident case selection for investigation was not made on a random basis as those cases which seemed to indicate possible violations of industrial codes or which had resulted in fatalities were most likely to be selected for investigation.

further grouped into 8 classifications of crane and hoist accidents given in Table 5-2. These classifications of crane and hoist accidents were used further in this study to solicit responses on hazards and hazard controls from manufacturers, managers and workers interviewed. The classifications also provide the topic outline for presenting the details of accident and interview results later in this section.

While the W. C. Case History file information could not be used to develop accident classifications, by roughly assigning accident type categories from the Case History file to the various classifications of crane accidents from the above analysis; quantitative, cost and other descriptive estimates of the nature of crane and hoist accidents can be made from this data. The Worker's Compensation data shows 1,646 cases from 1972 through 1975, due to cranes or hoists as the coded source of the accident. This is .83% of the total W. C. cases reported. The costs of these accidents (indemnity payments plus medical costs) are $1,418,220 or 1.11% of the total W. C. costs. The cases indicating cranes or hoists as sources of accidents probably represent only a fraction of the accidents with crane or hoist involvement. Only 1/2 of the employe promptness reports, selected by causal description information, were coded with cranes or hoists as the accident source on the data file. This assessment is based on a case-by-case comparison of the cases reported from the employe promptness reports with the cases as they are reported on the data file. Of the 413 employe promptness reports selected for analysis on the basis of an indication of crane or hoist involvement, only 144 cases were source coded as cranes or hoists on the Worker's Compensation file.

Tables 5-3 through 5-5 show cross tabulations of data from the W. C. file. Table 5-3 is a cross tabulation of accident type code groups, with the accident type code groups, with the accident source classification of crane or hoist reported and coded on the W. C. file; this provides a basic summary of the nature of accidents involved in the use of various types of cranes. Tables 5-4 and 5-5 are based on data from 1971 through 1975 on the W. C. Case History file and they show breakdowns by accident type groups and coded source classification of crane or hoist for the 2-or 3-digit SIC (Standard Industrial Classification) groupings indicated. These two tables give an overview of various industries' accident experiences in the use of cranes and hoists. Other than Tables 5-4 and 5-5, all W. C. data referred to in this report will be based on 1972--1975 Worker's Compensation data.

INTERVIEW AND FIELD OBSERVATION DATA SUMMARY

As indicated in Section II of this chapter, ten industrial establishments were visited in the course of this project to discuss and observe crane or hoist operations. At five of these establishments interviews with workers were carried out on the shop floor. The worker interviews centered around a determination of what hazards or hazard controls they felt existed in their job situation and experience in relation to various aspects of crane or hoist operations hazards. These aspects of crane and hoist hazards (loads falling, moving lifted loads, getting caught in cranes and hoists or loads and slings, machine functions and/or maintenance, overexertion in load

TABLE 5-2
CLASSIFICATION OF ACCIDENT CATEGORIES FOR CRANES AND HOISTS FROM 1974 EMPLOYE REPORTS

I. Lifted items or other load elements falling when hoisted to cause injury, from................................		
A. Loads being lifted which slip from hooks, chains, slings, etc. to injure workers.........	97 cases	23.5%
B. Loads or parts of loads hook up falling from crane or hoist to injure, due to breakage of hooks, cables, chains, etc.........	25 cases	6%
C. Loads falling from cranes or hoists, not specifiable..............................	12 cases	3%
D. Crane or hoist mishooking and tipping to cause injury..............................	2 cases	.5%
TOTAL	136 cases	33%
II. Load being moved by cranes or hoist, or part of crane or hoist moving load, striking some object and causing injury, from............................		
A. Workers struck by loads being moved or by parts of crane or hoist while machine is moving....................................	36 cases	8.75%
B. Loads or parts of cranes or hoists hitting other objects while moving and falling or causing something else to strike injured.......	16 cases	3.75%
C. Injured getting pinned between moved load and other object..............................	15 cases	3.75%
D. Load or part of hoist lowered or injured.......	8 cases	2%
E. Overhead and other cranes running into injured..	7 cases	1.75%
F. Crane operators injured by collision...........	2 cases	.5%
TOTAL	85 cases	20.5%
III. Worker gets caught in or between loads lifted or prepared for lifting, and/or crane or hoist parts, from..		
A. Workers injured by being caught between lifted loads and/or hook up elements of hoist or crane (hooks, slings, chains, etc.)..	37 cases	9%
B. Workers getting caught in mechanical parts of hoisting mechanisms..................	14 cases	3.5%
C. Worker pinned between piles of material while hooking them...........................	4 cases	1%
TOTAL	55 cases	13.5%

TABLE 5-2 continued

IV. Injuries involving some failure, malfunction or misoperation of crane or hoist mechanisms or structures, from...		
A. Crane or hoist of integral part of crane or hoist (boom, anchor hardware, etc.) failing and/or falling to cause injury..................	30 cases	7.3%
B. Slippage in the lift mechanism of the crane or hoist which causes load to fall or machine to jerk and result in injury...........	20 cases	4.7%
TOTAL	50 cases	12%
V. Injuries incurred as a result of manipulation of the load in order to attach and hoist it, or from manually participating in the moving of loads, from...		
A. Overexertion in operation (moving loads) of crane or hoist..............................	18 cases	4.3%
B. Operator of crane or hoist injured by an object not part of the crane or hoist while operating (tripping or falling over object..	10 cases	2.5%
C. Manuvering materials to load on or hook to crane or hoist............................	7 cases	1.7%
TOTAL	35 cases	8.5%
VI. Injuries involving workers operating around or on crane hardware and/or entering or leaving crane cabs, from..		
A. Worker falling or stepping off crane or hoist..	18 cases	4.2%
B. Worker injured climbing into crane.............	4 cases	1%
C. Worker falling from overhead crane rail........	2 cases	.5%
TOTAL	24 cases	5.7%
VII. Injuries from crane or hoist maintenance operations not otherwise covered, from.................................		
A. Workers injured setting up or disassembling a crane or hoist..............................	8 cases	2%
B. Worker injured replacing a cable on a crane or hoist (mainly falls)........................	6 cases	1.5%
TOTAL	14 cases	3.5%
VIII. Remaining categories		
A. Bumping into a stationary crane or hoist to injure self...............................	4 cases	1%
B. Contact with electricity through cranes........	3 cases	.7%
C. Ergonomics in crane design (of cab controls....	2 cases	.5%
D. Cranes and hoists not determinable.............	10 cases	2.5%
TOTAL	19 cases	4.7%
GRAND TOTAL	413 cases	

TABLE 5-3

CRANE AND HOIST EQUIPMENT TYPES BY ACCIDENT TYPE GROUP, FROM 1972 TO 1975 WORKER'S COMPENSATION DATA

Accident Type → / Equipment Type ↓	Total # Cases	Percent Cases	Fall or Bump Against	Struck by Falling Load or Part	Struck by Moving Part of Equipment	Struck by Unspec.	Caught Between Moving & Stat. Obj.	Caught in Equip.	Caught in Unspec.	Pedestrian Struck By	Contact with Power Lines	Contact Elect. Thru Equip.	Overexert. in Handle or Operate	Other Types
Overhead Crane	121	7.3%	5	71	22	2	1	7	3	--	--	1	4	5
Bridge Crane	3	.2%	--	--	1	1	--	--	--	--	--	1	--	--
Traveling Crane	1	.1%	--	--	--	--	1	--	--	--	--	--	--	--
Monorail Crane	4	.2%	--	--	2	--	--	1	--	--	--	--	--	1
Derrick	3	.2%	2	--	--	1	--	--	--	--	--	--	--	--
Dredge	1	.1%	--	--	--	--	--	--	--	--	--	--	1	--
A-Frame Crane	1	.1%	--	1	--	--	--	--	--	--	--	--	--	--
Lumber Lift and Jammer	4	.2%	--	1	--	--	1	--	1	--	--	--	--	1
Jib Pillar Crane	33	2.0%	1	20	4	--	--	3	--	--	--	--	4	1
Tank Rig	2	.1%	--	--	--	--	--	1	--	--	--	--	--	1
Crawling Crane	12	.7%	6	--	1	--	--	2	1	1	--	--	1	--
Long-Boom Tractor Crane	1	.1%	--	1	--	--	--	--	--	--	--	--	--	--
Magnet Crane	19	1.2%	--	15	--	--	--	1	1	--	--	--	2	--
Truck Crane	44	2.7%	1	4	14	--	1	1	--	2	12	--	--	9
Hydraulic Crane	18	1.1%	--	5	4	1	--	4	2	--	1	--	1	--
Erecting Crane	3	.2%	--	1	1	--	--	--	1	--	--	--	--	--
Electric Hoist	20	1.2%	--	9	3	1	--	3	--	--	--	1	--	2
Air Hoist	9	.5%	--	3	--	--	1	1	1	1	--	--	[illegible]	--
Chain Hoist	168	10.2%	6	59	[illegible]	1	2	20	17	--	--	--	21	2
Block & Tackle	12	.7%	1	--	3	1	--	4	--	--	--	--	2	1
Construction Materials Hoist	8	.5%	--	--	1	--	--	4	2	--	--	--	1	--
Hand Hoist	53	3.2%	--	25	5	--	--	1	5	--	--	1	17	3
Winch	81	4.9%	3	10	27	1	--	12	8	1	--	--	15	4
Hoist Apparatus Not Specified	47[illegible]	29.0%	47	109	64	24	14	42	24	--	2	--	46	25
Crane Not Specified	546	33.1%	56	225	79	20	9	43	5	6	17	4	39	43
TOTAL (PERCENT)	1646 (100%)		12[illegible] (7.8%)	539 (3[illegible]%)	263 (16.0%)	53 (3.[illegible])	30 (1.[illegible]%)	15[illegible] (9.[illegible])	[illegible] (4.[illegible]%)	10 ([illegible]%)	33 (2.[illegible])	8 (0.5%)	156 (9.5%)	97 (5.[illegible])

TABLE 5-4

INDUSTRIAL GROUPS BY ACCIDENT TYPE GROUPS, FROM 1971 TO 1975 WORKER'S COMPENSATION DATA

ACCIDENT TYPE → / INDUSTRY CLASSIF. ↓	TOTAL # CASES	PERCENT CASES	FALL OR BUMP AGAINST	STRUCK BY FALLING LOAD OR PART	STRUCK BY MOVING PART OF EQUIPMENT	STRUCK BY UNSPEC.	CAUGHT BETWEEN MOVING & STAT. OBJ.	CAUGHT IN EQUIP.	CAUGHT IN UNSPEC.	PEDESTRIAN STRUCK BY	CONTACT WITH POWER LINES	CONTACT ELECT. THRU EQUIP.	OVEREXERT. IN HANDLE OR OPERATE	OTHER TYPES
MACHINERY MFG. EXCEPT ELECTRICAL	451	23.2%	24	244	51	11	11	36	14	3	--	3	45	9
PRIMARY METALS	275	14.4%	9	143	37	11	5	30	12	1	--	2	21	4
FABRICATED METAL PRODUCTS	224	11.6%	9	114	32	11	3	18	10	--	--	--	20	7
SPECIAL TRADE CONTRACTORS	106	5.3%	10	31	16	4	6	16	2	2	5	--	10	4
DURABLE GOODS WHOLESALE TRADES	97	4.5%	18	32	11	1	2	11	1	--	4	2	6	9
HEAVY CONSTRUCTION	96	4.6%	14	28	20	1	--	13	2	1	9	--	6	2
TRANSPORTATION EQUIP. MFG.	82	4.3%	3	40	12	6	4	5	2	--	--	--	9	1
GENERAL BUILDING CONTRACTORS	79	4.0%	18	27	15	1	2	4	2	--	3	--	4	3
TRUCKING AND WAREHOUSING	65	3.3%	5	16	12	1	2	8	2	1	3	--	13	2
AUTO DEALERS AND SERVICE STATIONS	50	2.6%	16	14	6	3	2	2	5	--	--	--	8	2
STONE CLAY AND GLASS PRODUCTS	51	2.4%	8	7	10	1	1	4	2	--	7	1	5	5
FOOD AND KINDRED PRODUCTS	40	2.6%	2	13	9	3	2	7	4	--	1	--	6	2
PAPER AND ALLIED PRODUCTS	44	2.2%	5	5	11	2	1	9	4	--	--	--	4	3
PUBLIC ADMINISTRATN.	42	2.2%	2	10	8	1	--	7	3	--	2	--	6	4
SERVICES	42	2.2%	2	13	12	3	--	6	3	--	--	--	1	2
LUMBER AND WOOD PRODUCTS	39	2.0%	4	11	8	--	1	4	4	--	2	--	3	2
ELECTRICAL AND ELECTRONIC EQUIP.	31	1.6%	1	15	2	--	1	6	1	--	--	--	4	1
TELEPHONE, ELECT, GAS & SANITARY UTILITIES	29	1.5%	--	4	9	3	1	4	--	--	4	--	2	2
RETAIL TRADE OTHER THAN AUTOMOTIVE	23	1.2%	1	5	4	1	2	4	2	1	2	--	--	1
NONDURABLE GOODS WHOLESALE TRADE	12	.6%	1	3	1	1	--	--	--	--	--	--	5	2
AGRICULTURE, FOREST, AND FISHING	11	.6%	--	3	2	2	--	1	1	--	1	--	--	1
MINING	11	.5%	3	1	2	--	--	--	2	1	1	--	--	1
PRINTING AND PUBLISHING	10	.5%	2	3	2	--	--	1	--	--	--	--	2	--
INSTRUMENTS AND RELATED PRODUCTS	7	.4%	--	3	--	--	--	1	--	--	--	--	2	1
OTHER INDUSTRIES	35	1.9%	--	10	5	3	1	5	4	--	--	--	4	3
TOTAL (PERCENT)	1971 (100%)		157 (8.0%)	795 (40.3%)	297 (15.1%)	70 (3.5%)	47 (2.4%)	202 (10.2%)	82 (4.1%)	10 (.5%)	44 (2.2%)	8 (.4%)	186 (9.4%)	73 (3.7%)

TABLE 5-5

INDUSTRIAL GROUPS BY GENERAL EQUIPMENT TYPES OF CRANES AND HOISTS, FROM 1971 TO 197? WORKERS' COMPENSATION DATA

EQUIPMENT TYPE			GENERALLY HOISTS OR SMALL CRANES							SPECIAL HOISTS		SMALL TO MED. SIZE CRANE SYSTEMS					MOBILE CRANES AND LIFT SYSTEMS							MEDIUM TO LARGE FIXED SITE CRANES				NOT SPECIFIED	
INDUSTRY CLASSIF.	TOTAL CASES	PERCENT CASES	CHAIN HOIST	WINCH	HAND HOIST	ELECTRIC HOIST	AIR HOIST	BLOCK AND TACKLE	CONSTRUCTION MATERIALS HOIST	TRAVEL LIFT	TACK RIG.	JIB PILLAR CRANE	MONORAIL CRANE	A-FRAME CRANE	JAMMER	LUMBER LIFT	TRUCK CRANE	HYDRAULIC CRANE	CRAWLING CRANE	LONG BOOM TRACTOR CRANE	ERECTING CRANE	DERRICK	DREDGE	OVERHEAD CRANE	MAGNET CRANE	BRIDGE CRANE	TRAVELING CRANE	HOIST APPARATUS NOT SPECIFIED	CRANE NOT SPECIFIED
MACHINERY MFG. EXCEPT ELECTRICAL	462	24.4%	47	3	17	5	2			1		24	1	1				3	4	1	2	2		64	9			91	106
PRIMARY METALS	283	14.3%	42		5		8	2			1	2	1											27	1	1	1	96	106
FABRICATED METAL PRODUCTS	223	11.3%	24	3	11	1		2	1	2		4	1					1	1					26	6	1		58	79
SPECIAL TRADE CONTRACTORS	102	5.2%	11	6	3	1		1	6			1	1		1		5					1		1				25	39
DURABLE GOODS WHOLESALE TRADE	91	4.6%	8	5				1	2			2					4	1	2					1	5			11	47
HEAVY CONSTRUCTION	90	4.6%	6	1				1			1	1		1			9	3		1				1		1		9	55
TRANSPORTATION EQUIP. MFG.	86	4.4%	8	3	1	2	1					1												5		1		40	24
GENERAL BUILDING CONTRACTORS	67	3.4%	2	2	1	1											4	2		1	1							18	35
TRUCKING AND WAREHOUSING	63	3.2%	1	32	1											1	3	1	1			1		2	1			7	12
AUTO DEALERS AND SERVICE STATIONS	57	2.9%	1	3	2		2			1								5										37	6
STONE CLAY AND GLASS PRODUCTS	46	2.4%	4	2	1			1									7			2		1		4				15	11
FOOD AND KINDRED PRODUCTS	49	2.5%	5	6	2	1	1										1	1						1				23	6
PAPER AND ALLIED PRODUCTS	45	2.3%	6	2	1	2																		4				24	6
PUBLIC ADMINISTRATION	44	2.2%	5	8		1	1	1									5	2	1	1				1				9	9
SERVICES	43	2.2%	4	3	1	1					1	1					2	1						2				20	7
LUMBER AND WOOD PRODUCTS	39	2.0%	3	2	2	2		1								2	1		2					5				11	8
ELECTRICAL AND ELECTRONIC EQUIP.	32	1.6%	2		2	3	1					1												1				10	12
TELEPHONE, ELECT., GAS & SANITARY UTILITIES	29	1.5%	2	6	2												7	1										7	4
RETAIL TRADE OTHER THAN AUTOMOTIVE	24	1.2%	2	3													3	1	1					1				11	2
NONDURABLE GOODS WHOLESALE TRADE	13	.6%	1		2	1																						6	1
AGRICULTURE, FOREST, AND FISHING	11	.6%	1	2	1		1										1	1										2	2
MINING	10	.5%	1	1													2							1				2	1
PRINTING AND PUBLISHING	9	.4%	1																									2	
INSTRUMENTS AND RELATED PRODUCTS	8	.4%	2		2	3																						1	
OTHER INDUSTRIES	41	2.1%	7	2			1	1				1						1		1			1	1				19	6
TOTAL	1973		199	95	57	26	17	12	10	4	3	38	4	2	1	3	54	24	12	7	3	5	1	149	22	4	1	552	668
PERCENT	100%		10%	5%	3%	1%	1%	.6%	.5%	.2%	.2%	2%	.2%	.1%	.1%	.2%	3%	1%	.6%	.3%	.2%	.3%	.1%	8%	1%	.2%	.1%	28%	34%

handling or machine operations, and accessory availability--slings and attachments) corresponded to the general nature of hazard indicated by the eight classifications of crane and hoist accidents generated in the data analysis (Table 5-2). Workers were also asked to indicate what they felt was the major hazard involved in crane and hoist use before being asked to comment on each of the aspects of operations hazards.

There were 90 discussions with workers carried out, each generating comments on various of the hazard categories of differing depth and specificity. Crane and hoist operators made up 42 of these interviews, with the balance of the interviews involving load hitchers and maintenance or inspection personnel involved with cranes, hoists and slings.

In addition, notes were taken during seven discussions of various issues involved in the use of cranes and hoists with management and engineering staff of the establishments visited. While this information is not included in the hazard analysis data, it will be mentioned when pertinent to the discussions in this chapter.

The comments made by workers were analyzed in a manner outlined in Section II of this chapter. The results of this analysis of workers' comments on crane and hoist hazards and hazard controls will be incorporated in the discussion to follow in this chapter. The remainder of this section will involve discussions of the accident description and causation factors, and hazard and hazard control comments from workers which relate to classifications of crane and hoist accidents paralleling those given in Table 5-2.

ACCIDENT FACTORS ANALYSIS AND WORKER INTERVIEW RESULTS

The following seven segments of this section will present the most salient points of the accident data analysis and field survey interviews with users of cranes and hoists. The format for these segments will be to introduce and define a classification of accident type or hazard type. Following this description, the accident analysis results will be summarized. This summarization will be an expansion on the information presented in Tables 5-1 through 5-5, especially Table 5-2 which presents classifications of crane and hoist accidents roughly parallel to those which follow.

Next, the results of comments regarding hazards gathered during the field observation interviews will be summarized. The major groups of hazards pointed out by the 90 workers interviewed as well as the protective and preventive measures workers and managements have taken or suggest are presented in Tables 5-6 through 5-12. These tables will be accompanied by some explanatory narrative for each classification.

A. LOAD OR LOAD ELEMENTS FALLING FROM HITCHING SYSTEM MALFUNCTION OR FAILURE

This classification, Classification A, corresponds to hazards and accidents which indicate the system connecting a load item to a crane or hoist falling in some way, and dropping the load. Classification A attempts to exclude factors of crane failure or physical misoperation (malfunction, roughness, etc.) which are related to loads falling, which are described in Classification D.

Accident Analysis Results

Accidents assigned to this classification accounted for 33% of the accidents related to crane usage from the promptness survey, and 27-1/2% of the accident investigations related to crane operations. The Worker's Compensation file indicated 39% of the cases, implicating cranes or hoists as the main accident source, involved falling objects or materials from equipment striking and causing injury. The total Worker's Compensation costs attributed to these types of accidents was $559,218 (cost from the W. C. file for accidents, source coded as cranes or hoists).* These accidents most often result in injury to a worker's feet.

Causal information from the employe promptness reports and accident investigations, generated three categories into which the cases in this classification (lifted items or load elements falling when hoisted) fit: 1) accidents due to load or hitching hardware slippage; 2) accidents due to breakage of hitching hardware or part of load; and 3) a few cases implicating mishooked loads tipping when lifted.

These accidents are those which correspond roughly to reported accidents which were type coded to the "Struck by falling load or part" type code category.* Tables 5-3 and 5-4 show this type of category to be the most frequent type of accident reported for almost all types of cranes and hoists, and industrial classifications. Manufacturing industries often show over half of their crane and hoist injuries coming from this type of accident. Construction and other outdoor users of cranes showed this type of accident to be involved in one-fourth to one-third of their reported W. C. records.

The promptness survey reports indicated that the materials which fell and caused injury most often were (in order to most to least frequent): castings; various iron and steel items (plates, pipes, beams, etc.); molds and flasks; and various pieces of machinery. This data came primarily from workers in (in order of greatest frequency to least frequency): primary metal industries; machinery manufacture (especially construction machinery and electric motors manufacturing); and metal fabrication and forging. A lesser involvement is shown for the construction industry, utilities and sanitation services, and paper mills.

There were two main categories of causal factors in this accident classification: loads falling from load or hitching hardware slippage; and loads falling due to breakage of hitching hardware or breakage of part of the load. Factors associated with these categories were:

*Some of these cases may belong in Classification D, as Worker's Compensation Coding was not fine enough to discriminate between these two categories.

For loads, etc. slipping:

1) Loads or load attachments unhooking from sling or crane and hoist hooks.
   - failure or lack of safety latches
   - allowing cables to slack
   - improper hooking or using wrong or damaged hooks
2) Chains slipping or loads slipping from chains.
   - loads being manipulated when lifted and slipping
   - choker chains slipping on grab hooks
   - choker chains using improper hooks (swivel hooks)
   - loads not in balance
   - irregular shaped loads not securely hitched
3) Clamps slipping off loads (mainly steel plates) and hooks
   - improperly sized hooks
   - failure to attach clamps to hoist hooks with flexible slings and safety latch hooks
4) Items falling from magnets--exceeding magnet lift capacity.
5) Loads falling from various slings other than chains.
6) Loads falling when raised for maintenance or cleaning operations--unhooking, slipping.

For hitch hardware and load breakage:

1) Breakage of hoist or crane cables, cable slings
   - cable clamp end fasteners (dogs) not sufficient
   - lifting in excess of capacity and jerking loads
2) Hoist chains or sling chains breaking.
   - failing to repair (replace) chains with bad links
   - using unrated chains for lifting (nonalloy)
   - lifting in excess of capacity and jerking loads
   - chains crystallize from extremely hot temperature
3) Hooks bend or break--overloads and crystallization.
4) Eyebolts or hitch points on loads breaking--pulling in sideways directions.

Interview Results

The comments, related to this classification of accidents, made by workers interviewed during the field study segment of this project are summarized in Table 5-6. This classification of accidents, loads falling from hitching system malfunctions, generated nearly twice as many comments as did any other accident classification; in excess of 130 comments.

These comments basically fit into three categories: those dealing with the control that operators of cranes have in the process of handling loads safely; comments related to the load handling adequacy of slings and load attachment devices; and indications that the nature of the method in which the load is hitched is the key to avoiding loads falling when lifted. A comparison of the accident data analysis presented earlier with the comments indicated in Table 5-6 indicate that workers as group seem to be aware of the factors in crane and hoist use which are related to crane and hoist use accidents.

TABLE 5-6

A. SUMMARY OF HAZARDS AND CONTROLS RELATED TO LOADS FALLING FROM HITCHING SYSTEM MALFUNCTIONS - FROM WORKER INTERVIEWS.

I. LIMITATIONS TO THE CRANE OPERATORS CONTROL OF THE LOAD (40 Comments):

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Operator visibility limitations from equipment, worksite and operations designs or environmental conditions (e.g. in foundries from dust or molten metal incandescence; pendant controls operator's limitations on movement and position; and crane operator's visual restrictions when setting high steel, etc. in construction jobs). -Hazards to smoothly handling an attached load when it is lifted, moved or turned--loads shifting on their hitch. -Pedestrians in the path of a load who could be struck by a falling load or part. -Operator's limitations and the responsibility for checking hitches and slings.	-Close coordination is needed between the operator and the hitcher regarding the setting of hitches and signalling load lifts (pre-lift procedures communications). -Prior to using the crane the operator should check out its control functions. -Prior to load lifting, operator should check load path for obstructions or floor traffic (pedestrians, lift trucks, etc.), and make judicious use of horn or bell to alert floor traffic. -Check the hitchers selection of sling and hitch for adequate capacity and hitch balance before lifting. Center hoist overload. -Lift the load only a few inches at first to check hitch before raising to travel height. -Operate the crane in only one dimension of movement at a time. -When the operators vision is obscured, the operator should try to position himself to better see the load. If this isn't reasonable (operator gets strained, could fall from cab or ladder), vision holes or windows can be cut in the floors and sides of cabs; extra signal-relay personnel or communication equipment (radio or telephone system) should be used to transmit signals from hitcher to operator; operators who have to handle bright objects (molten metal) can use polarized glasses and use peripheral vision, lights could be used for signal communication; and where operators have to handle loads near welding operations, welders should stop welding while the operator has to look in their direction.	-Loads should be moved at as low a level as surrounding obstructions permit so if loads slip they can be lowered quickly or will only fall a short distance. -Don't move loads over people! -Make sure hitchers are clear of load when it is lifted.

II. HAZARDS RELATING TO SLINGS AND LOAD ATTACHMENT DEVICES (39 comments):

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Slings getting damaged and subsequently failing while lifting load. -Selecting slings insufficient in capacity or in configuration to safely lift and move a load.	-Slings should be stored in racks or lockers close to the work station at which they will be used - borrowed slings "disappear" too often. -Provide slings of adequate design or type (chain, wire rope or nylon) to safely handle loads at a given work station.	-When chains are used for lifting and any chance of chain failure exists, workers on the floor should give the load and sling a wide berth when loads are first lifted.

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TABLE 5-6 Continued

-Special attachment systems (magnets, clamps, vacuum devices, etc.) failing to sufficiently grip loads.	-Avoid damaging chains from: overload stretching, shock loading, crushing, welding arcs and excessive heat crystallization, sharp edges on loads (padding), and twisting or kinking chains in lifting. -Avoid damaging nylon strap slings from: cuts from sharp edges on loads (padding), stretching from overload or tight chockers, damage from heat exposure. -Avoid damage to wire rope slings from: kinking, repeated bending, loss of lubrication (rust), excessive internal or external wire breakage, twisting, and tight chockers. -Inspect slings for damage regularly before and after use. Damaged slings should be taken out of service for repair or evaluation and replacement (downrating may be feasible, but only after a specialist inspects the damage). Adequate substitutes for removed slings should be provided to meet the requirements for safe lifting. -Periodic inspection for metal fatigue should be made. -Attachment devices which hold loads from the top (magnets, plate clamps, hydraulic clamps, vacuum devices, etc.) should be regularly inspected and maintained for secure operations. Clamp teeth and grab edges should keep a sharp biting edge. Hydraulic systems should maintain pressures and not leak. Vacuum devices don't work well on rough surfaced loads or cold loads. -Hitchers should select slings they feel are sufficient to handle load size and weight. Operators of cranes should check the sling and hitch visually before lifting and not lift loads until they feel the hitch and sling are right.	-Wear gloves when using wire rope slings to protect hands from broken wires. -When loads are initially lifted they could shift and exert a maximum strain on the sling--workers should stay clear. -Workers should not walk under loads held by attachment devices which hold loads by pressure (clamps and vacuum devices) or magnets.

III. LOADS FALLING FROM AN INSUFFICIENT HITCH WHICH CAN INJURE HITCHERS OR OPERATORS AROUND THE LOAD.

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury If Hazard Develops
-Loads that can fall from improper hitching (off-center hitch; twisted or crossed chains, straps or ropes; improperly set hooks, etc.). -Loads falling when attachment points on loads break or fail (trunions, welded hitch points, wooden pallets). -Loads falling when the item lifted slips on the hitch (odd shapes, oily loads, cold weather loads).	-Hitchers and crane operators have to cooperate to safely handle loads. Crane operators will understand the hitchers problems better if they have some experience hitching (progression and training for crane operators should include hitching). Signals and procedures between hitchers and operators should be clear before they start lifting loads. -On large, irregular or unusual loads, information related to the load weight and center of gravity, as well as safe hitch points, should be supplied to the hitchers. Where possible, weight and center of gravity should be marked on odd-shaped pieces.	-Hitchers should make sure they have a clear escape path in case a load fails when lifted or moved. -Operators should try to lower loads quickly and safely if some problem develops in the hitch of a load after it is lifted. Horns and bells can be used to warn workers of load's proximity.

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TABLE 5-6 Continued

-Hitchers or pendant crane operators are injured by loads which twist or swing on their hitcher when moved or lifted and subsequently fall.	-Crane operators are in a generally better position than hitchers to make sure that slings aren't twisted or crossed and that the hitch and hoist are properly centered for the load. The hitcher has better vision of the lower parts of the hitch or the side of the load opposite the operator than the crane operator and can keep track of these parts of the hitch and load and signal problems to the operator. -Hitchers should be trained to know the capacity of slings in different configurations; also they should know the proper method for making the hitches they are required to make. Some hitchers felt sling capacity pocket cards helped, especially for irregularly shaped or sized loads. -Where the loads lifted by a floor operated pendant controlled crane are large or long, and the operator of the crane can't maneuver his controls enough to see or be clear of his load, the pendant operator should be moved up into a cab or some other elevated position where he has a good view of the load, hitchers and load path. -Where pieces have hitch points attached to them, these points should be welded or attached securely so they will support the weight of the load. Permanent hitch points like trunions on foundry flasks should be regularly inspected and repaired or removed if damaged.	-When working with small or medium sized loads, hitchers and other workers who work with hoists and cranes could be protected from injury by protective foot wear.

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The preventive measures workers indicated are those practices workers engage in or would like to be able to engage in to control the likelihood of loads falling from their hitches. In general, these preventive measures involved actions workers felt had to be performed by themselves or their co-workers prior to lifting loads (setting hitch: checking hitch, slings and hoist; etc.). The role of management in these preventive actions was seen basically as providing the mechanisms which would allow workers to carry out these preventive actions (adequate operator vision of hitch and load from operation station, training and enforcement of safe lifting practices, sling inspection programs, etc.). The protective measures indicated to lessen the chance of worker injury should loads fall centered primarily around workers keeping clear of loads being lifted or moved.

B. LOADS OR PART OF CRANE SWINGING OR MOVING INTO SOMEONE (OR SOMETHING) TO CAUSE AN ACCIDENT

The accidents and hazards involved in this classification (B) encompass those accidents and hazards which relate to a load being handled or a moving part of a crane colliding with some unintended object or person. These accidents seem to arise from loads or cranes in transit striking something; or from loads being lifted, swinging and striking or pinning someone in the proximity of the load.

Accident Analysis Results

Accidents assigned to this classification amounted to 20-3/4% of the accidents related to crane or hoist usage from the promptness survey, and 19-1/2% of the accident investigations related to crane or hoist operations. The Worker's Compensation File shows 17.8% of its cases, implicating cranes or hoists as the main accident source, involved workers injured when struck by a moving part of equipment, or from being caught between a moving and stationary object. An additional 2% of the crane or hoist accidents are the result of the crane or hoist colliding with a pedestrian or injuring the operator in a collision. The cost of these crane or hoist accident types is $204,893 or 14-1/2% of the Worker's Compensation costs attributed to cranes and hoists as an accident source.

There were six categories (see Table 5-2) of accident descriptions which fit into this accident classification: 1) Workers injured by loads being moved, or by part of crane or hoist mechanisms which they are moving: 2) loads or parts of cranes or hoists hitting some object while moving and causing something to fall or strike and cause injury: 3) part of a crane or hoist or a moving crane or hoist load pinning a worker against a fixed object; 4) load or part of a hoist lowered on a worker; 5) overhead or other types of cranes running into workers (pedestrians); and 6) crane operators injured in collisions.

The promptness survey reports indicated that the parts of the moving equipment or loads which cause the injury in these accidents are (greatest to least frequent): the crane hook or hook block; other moving crane or hoist part like booms, chains or cables; loads of metal (most commonly pipe, beam or plate): foundry items (flasks, molds and castings); and machinery or machinery parts being moved. This data was reported from workers in the following industries (in order of greatest to least frequency): Machinery Manufacture, except electrical (especially construction machinery manufacturing and speed changes, drives and gears manufacturing: Primary Metal Industries: Transportation Equipment Manufacture; Fabricated Metal Products (structural products and forging and stamping): Durable Goods Wholesale (industrial machines and scrap metal); and Paper and Pulp Mills. The types of cranes and hoists in these cases were overhead cranes: various boom type cranes (shovel crane, magnet crane, hydraulic crane, swing crane, etc.); chain hoists: electric hoists and jib cranes.

The causal factors which were found to be associated with the accident categories within this classification were:

1. Crane loads which are too low being moved or set swinging, and striking some object.
2. Hoists not positioned above loads causing the load to swing when lifted.
3. Loads shifting when lifted or moved causing the load to swing.
4. Crane boom or load swinging into an object causing load or object to fall.
5. Crane operated or load lifted too fast.
6. Crane or part of load and hitch catching on some object, breaking loose under tension and striking worker.
7. Operator not paying attention to signal man.
8. Malfunction in crane operation causing load to swing into objects.
9. Maintenance being performed on crane bridge without locking out crane or alerting the cab or pendant operator of the crane.
10. Work or maintenance being done on raised loads causing load to swing.

Interview Results

Worker comments related to this classification of crane and hoist accidents gave the second most numerous response: slightly more than 90 comments. These comments are summarized in Table 5-7.

Worker's comments related to loads swinging or moving into something unintended fit into three categories: those involving the operators of cranes and hoists and floor personnel's involvement and exposure in moving loads: hitching and load lifting problems possibly leading to loads swinging; and mechanical function or design aspects of cranes or hoists which can set loads swinging, or otherwise make loads more susceptible to striking something.

TABLE 5-7

B. SUMMARY OF HAZARDS AND CONTROLS RELATED TO LOADS SWINGING OR MOVING INTO SOMEONE (OR SOMETHING) TO CAUSE AN ACCIDENT - FROM WORKER INTERVIEWS.

I. HAZARDS RELATING TO CRANE OPERATORS' AND FLOOR PERSONNELS' INVOLVEMENT IN MOVING LOADS (52 comments):

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Floor traffic (hitchers, other pedestrians, lift trucks, etc.) vulnerability to moving loads carried below head level. This is a greater problem the greater the density of floor traffic below a crane, during shift changes, and where pedestrians are inattentive or disregarding of their surroundings. -Special vulnerability of hitchers and workers near loads from loads swinging when first lifted (loads shifting, attaining centered balance). -Pendant crane operators and hitchers who are exposed to possibly being caught between the load they lift and nearby machinery or stacks of materials. -Other obstructions in the possible path of a crane load (machinery, large pieces, storage racks, etc.) which load could strike--causing something fall. -In outdoor operations, wind and wind gusts can swing loads.	-Crane operators should preselect the path for the load to travel, check it for possible obstructions and for clearance of floor traffic before the load is lifted and moved. -Crane operators should try to keep track of pedestrian and floor traffic below them so they don't forget about someone if they walk out from behind a blind spot. Mirrors can help operators blind spot vision where operator is at a fixed station. -Hitchers and crane operators should stay in visual communication while moving loads so the operator knows the hitcher is safe and the hitcher can signal operator regarding path clearance from hitchers perspective. -Storage around crane and hoist lifting stations should be stable and orderly to allow safe hitcher, pendant operator clearance. When production increases, floor areas get more crowded, decreasing the safe work area. -Where pendant cranes or hoists are used, especially to handle long or large loads, pendant controls should allow operators to stay outside of a loads' swing radius. Hitching equipment to lift loads with controlled spin should be used. -When weather gets windy in outdoor crane work, especially high construction work should stop (booms lowered if winds become sufficiently strong). -Operators of cranes should use their warning devices (horns and buzzers) to alert inattentive floor personnel of a load in their working proximity. -Warning devices shouldn't be overused to alert people routinely or they will stop paying attention to it. -Pendant controlled cranes need operator controlled warning devices, not just automatic crane start-up bells or horns.	-Hitchers and pendant hoist and crane operators should be cautious and avoid (if possible) positioning themselves between stationary objects and loads to be lifted which may twist or swing. -Hitchers and pendant and rope controlled hoist operators should have a clear path in mind to escape a load should it swing or twist. -Operators of cranes should have load warning devices to signal floor traffic if a load gets out of control.

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TABLE 5-7 Continued

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
II. HITCHING AND LOAD LIFTING PROBLEMS POSSIBLY LEADING TO LOADS SWINGING (15 comments):		
-Loads swinging because of loads swinging or twisting when lifted--generally from loads stabilizing in their hitch (balancing with hoist shifting) when lifted. Exposing hitchers and others in the load's immediate vicinity to possible injury. -Loads which twist or swing easily when handled due to hitch system.	-Hitchers should make sure the load is hitched to avoid turning or settling or, if load is designed to be turned as lifted, anticipate the direction and position themselves appropriately when load is lifted. -Operators of cranes and hoists should insure that their hoists are centered above their loads, and that hitchers appear proper for lift. -Loads being handled or guided when moved or moved around floor traffic should be hitched so their twist and swing will be controlled (ie., not using single basket hitches on long loads; proper use of nonrotating rope on single line hoist cables, or using hook spinners to minimize the tendency of loads spinning or twisting, etc.).	-Hitchers and other floor traffic [illegible] loads being lifted should stay out of the possible swing radius of a load and keep an eye on the operator while he lifts and moves the load. -Avoid getting in a position to get trapped between a swinging load and a fixed obstacle.
III. HAZARDS TO LOADS SWINGING INTO SOMEONE FROM THE MECHANICAL FUNCTION OR DESIGN OF A CRANE OR HOIST (28 comments):		
Nature of Hazard	**Measures Indicated to Prevent Hazards from Developing Into Accidents**	**Measures Indicated to Protect Against Injury if Hazard Develops**
-Loads set swinging from jerky or uneven operation of cranes or hoists. -Loads set swinging from the braking action of a crane or hoist. Brakes that grab will jerk and swing loads, loose brakes will allow loads to slide. -Cranes and hoists with no hoist brake using directional controls to stop loads (lift control to stop a right moving load and vice-versa) or requiring hoist or crane operators to grab the load or crane cable to stop the load, can set loads swinging. -Crane bridges can slide on worn spots in support rails.	-Operators should check machine controls before lifting loads with cranes to insure the safe and smooth function of the crane. Improperly operating machines shouldn't be used until properly operating. Controls lubrication on a regular basis can keep cranes running smoothly longer. -Where brakes on cranes and hoist trolleys must be applied precisely to move or hold loads properly, these cranes should be run by an operator in an operating station attached to the crane so he can utilize the feel he gets from the crane's brakes (operators control feedback). -Where loads are large or have to be moved to locations by pendant controlled cranes which don't allow the pendant operator to hold the pendant and safely see traffic around the load, the operator should be placed at an operating station where he (she) is able to see around the load adequately (or at least be given signal personnel to help move the load). -Brake functions should be regularly checked and their sensitivity and efficiency properly maintained (including some self-adjusting brakes that don't properly adjust). Crane operators should be happy with the sensitivity of their cranes' brakes.	-Pendant and hoist operators, as well as hitchers who work around cranes with poor brakes, should stay cautious of their position relative to moved loads. -Other measures indicated in this table.

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TABLE 5-7 Continued

-Crane operators whose vision around the load is partially obscured by their equipment's design or limitations and can't see floor traffic around the load (cab operator's vision blocked by cab floors or walls, pendant operators whose pendant cables won't stretch to allow them to reach, see or move around the load, mobile cranes with rotating booms and fixed cabs have limited operator vision angles).	-Crane cabs whose sides or floors limit the operator's vision around loads near the cab should have vision holes or windows put into the cabs is possible (structurally) and/or have hitchers or others signal them regarding traffic in their blind spots. -Mobile cranes with 360° boom swings and fixed cabs should try to limit the angle of the boom to in	

The preventive measures related to work site activities primarily indicated the crane operator's control of the lifting and movement of loads and limitations on the ability of the operator to carry out his operations safely. Other preventive measures involved the load's hitcher properly attaching loads so they don't shift, twist or swing when lifted and moved. Other comments regarding hitchers and other floor traffic around loads were protective in nature involving floor traffic staying clear of loads which could possibly injure them.

Preventive measures tied to management decisions (not worker controlled) in equipment selection, work path and work station layout, and maintenance and inspection of equipment were also mentioned or implied in workers' comments. One type of equipment accessory--warning devices and their subsequent use was frequently indicated as a protective and preventive measure.

C. WORKER'S FINGERS OR BODIES GETTING CAUGHT IN LOADS BEING LIFTED, BEING HITCHED FOR LIFTING, AND IN CRANES OR HOIST PARTS

These hazards and accidents are those which involve workers handling loads or working on or with hoists and cranes getting part of their body injured by caught in or caught between (pinch points, getting pinned) accidents. These accidents arise primarily from load hitching, equipment maintenance and materials stacking collapse.

Accident Analysis Results--

As indicated in Table 5-2, this classification of crane and hoist accidents accounted for 13-1/2% of the cases found to relate to cranes and hoists in the employe promptness data, and 8% of the crane or hoist related accident investigations. These accidents correspond to crane and hoist source coded accidents with type coding of caught in or between equipment or moving objects. The data from the Worker's Compensation file indicates that approximately 14% of the crane or hoist coded accidents were due to the types of accidents indicated above. These accidents had a total Worker's Compensation cost of $177,480 or 12-1/2% of the costs for accidents whose sources were coded as a crane or hoist.

Three categories of accident types were found to fit into this classification: 1) accidents involving workers who get caught in or between lifted loads and/or hookup elements of hoist or crane (hooks, slings, chains, etc.-primarily injury hands); 2) workers getting caught in mechanical parts of hoisting mechanisms: and 3) workers pinned between piles of material while hooking them. Of these categories, the first type of accident--workers getting fingers and hands caught in lifted loads--accounted for the bulk of the accidents in this classification.

The promptness survey results indicated that the types of materials and hoist elements which workers get caught in or by were (in order of most to least frequent): chains and steel loads, flasks, coils, other chains, boxes or molds: hooks and their attachments; clamps and loads; cables; and slings and lifted machines. The mechanical parts of hoisting mechanisms which workers most often got caught in were: cables and pulleys; chains and hoists; hook blocks and cables or chains; hoist levers; hoist trolley and tracks; and crane drive shafts. When workers are pinned between the piles of materials being hitched, these items are usually cylindrical objects like metal pipes or logs. The industries from which these reports come are: Fabricated Metal Products (boiler shops and iron and steel forging, mainly involving caught in lifted loads and attachment cases); Primary Metals Industries (especially gray iron foundries); Machinery manufacture--except electrical (especially construction machinery manufacture, only cases involving caught in lifted loads and attachments accidents); and to a lesser degree, the Paper Products and the Transportation Equipment Manufacture Industry. The crane types involved in these accidents were (most to least frequent): chain hoists, overhead cranes; electric hoists; winches; hydraulic cranes and air hoists.

Causal factors reported and investigated for caught in and caught between accidents were:

1. Operators misunderstanding or ignoring signals from hitchers and prematurely lifting loads.

2. Miswiring or mistaking operation of pendant lift and lower controls.

3. Loads or cables being guided or held, moving and catching fingers.

4. Hitcher holding on to hook or sling when load is lifted.

5. Maintenance operations being performed on cranes or hoists not locked out.

6. Lack of proper pinch point guards.

7. Brakes or crane drive functions not working smoothly causing loads to shift and catch fingers, etc.

Interview Results

The comments made by interviewed workers related to caught in accidents are summarized in Table 5-8. Workers making comments on this category of hazard made relatively few comments considering the relatively large percentage of crane and hoist accidents this type of accident represents. Workers made 38 comments found to relate to this category; this small number may indicate that workers don't give these types of hazards the respect they deserve.

These comments fit into three general categories: Caught in hazards from hitching loads and the operations of the crane (hoist) in lifting the load, generally involving the hitchers exposure to situations where he (she) can get caught or pinched: physical elements of the hitching system or the hitcher's hands (rings and gloves) which could increase the chance of caught in injury; and caught in hazards involved in maintenance operations and pendant hoist and crane operators holding loads to get guidance feedback. Table 5-8 gives a summary of comments made regarding these categories.

TABLE 5-8

C. SUMMARY OF HAZARDS AND CONTROLS RELATED TO WORKERS GETTING CAUGHT-IN LOADS BEING LIFTED, BEING HITCHED, AND IN CRANE OR HOIST PARTS - FROM WORKER INTERVIEWS.

I. CAUGHT-IN HAZARDS ARISING OUT OF THE HITCHING OF A LOAD AND THE OPERATION OF THE CRANE IN LIFTING IT (29 comments):

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing to Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Hitchers and operators screwing up signals resulting in early lifts--often involving more than one hitcher signalling operator at a time or limited operator vision of hitcher. -Operators lifting loads before hitcher is finished or ready. -Hitchers approaching load, touching hitch or load and getting hurt--(e.g. grabbing a moving load to stop or steady). -Hitchers having to hold hooks or slings to properly set hitch.	-Hitchers and operators should have a lift signalling system worked out that allows the hitcher to indicate to the operator when he is ready for a lift. For this to work, operators should have a clear view of the hitcher or someone relaying signals from the hitcher. Operators may instruct hitchers where to stand during lift. -When more than one hitcher is involved, it should be determined ahead of time who will give the operator signals. -Hitchers, where possible, should stay clear of a load when lifted unless they signal the crane operator and get a clear signal back. -Lift signals shouldn't be given until loads are ready. -Hitchers who have to hold hooks or chain slings to set hitches properly should hold the back side (away from load) of hooks and slings, avoid pinch points and don't stand with their back to the operator. When slings are being set they should be tightened enough to set the hitch but not lift the load until hitcher is clear, hitch is checked and all is clear.	-Hitchers should try to keep their hands visible to the crane operator and the operator should keep an eye on the hitcher so if he gets caught, the load can be lowered (e.g. hitcher shouldn't turn back on operator when the load is lifted).

II. PHYSICAL FACTORS HAZARDS TO GETTING CAUGHT-IN, USING CRANES AND HOISTS (5 comments):

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing to Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Workers getting rings or protective gloves caught in hooks, slings and loads. -Hoists and jib and rail type small cranes whose lack of hoist travel brakes require workers to grab loads on hitch blocks to stop loads--could get pinched.	-Don't wear rings if you hitch loads; protective gloves should fit tightly but be able to slip out of; unless necessary, these gloves should not be bulky. -When grabbing loads or hook blocks, avoid pinch points. -Select properly sized slings to safely make lifts. -Often single or double-wrapped basket slings (wire rope) can more safely replace wire rope choker slings.	-Stay clear of wire rope slings (especially chokers) when loads are set down, until all tension is off the sling.

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TABLE 5-8 Continued

-Aspects of certain slings which can increase caught-in chances (e.g. slings with hook rings too small for cranes or hoist hooks; wire rope chockers may twist when the tension of the load is relieved, catching a finger).		
III. CAUGHT-IN HAZARDS IN REQUIREMENTS FOR PROPERLY HANDLING LOADS AND CRANE AND HOISTING EQUIPMENT (4 comments):		
<u>Nature of Hazard</u>	**<u>Measures Indicated to Prevent Hazards from Developing to Accidents</u>**	<u>Measures Indicated to Protect Against Injury if Hazard Develops</u>
-Caught-in hazards which can result from maintenance operations involving cranes and hoists. -Pendant crane operators and operators of hoists who have to hold loads in order to get feedback of the load's movement (i.e. could get caught in hook or sling, hoist running [illegible], etc.--this is more likely if the hoist controls operate jerkily).	-When maintenance is being done on hoist assemblies, hook blocks, running ropes, etc. the hoist's drums should be blocked to avoid turning, running ropes clamped and hoist blocks clamped. -Maintenance personnel shouldn't wear glasses or hats unless they are attached to their person. If these were to fall, a person may make a reflex move to grab them and possibly get caught in the equipment being worked on (or fall). -Pendant operators who have to hold loads to get guidance feedback should hold loads, not slings, and keep hands clear of pinch points.	-No protective comments made.

The principal protective and preventive measures indicated activities the hitcher and operator should engage in to reduce caught injury likelihood or extent. Those comments relevant to management or supervisory activity, principally involve providing a sufficient work place or encouraging effective work practices (signal use and signal personnel) to get the job done safely.

D. CRANE OR HOIST MECHANISMS OR STRUCTURES: MALFUNCTIONING, MISOPERATING OR FAILING--RESULTING IN HAZARDS (ACCIDENTS FROM FALLING ITEMS)

The hazards and accidents described in this classification involve those hazards or accident reports indicating the involvement of some operational shortcoming in the mechanisms or structural elements of a hoist or crane. The accidents or potential accidents these hazards relate to are the results of workers getting struck by (pinned by or between, etc.) some falling object (loads or parts of hoist or crane system). These incidents and comments differ from those in Classification A (falling items from hitching system malfunction or failure) by the emphasis of the crane or hoist system's operation as a causal element in the accident report or hazard statement.

Accident Analysis Results--

This accident classification accounted for 12% of the accidents selected from the promptness survey which showed the involvement of cranes or hoists. Inspected accidents in this classification accounted for 13% of the investigations of cases showing cranes or hoists as principal factors in the accident.

It is difficult to correlate the accidents described in this classification with the type groups of Worker's Compensation coding system. Some of the accidents described in this section might be described by the code for workers injured when struck by a falling object when cranes or hoists are the corresponding source code, but other type codes correspond to the cases found to fit this classification of employe reports. For this reason, no estimate of costs is available from the Worker's Compensation Data.

The categories of accidents which make up this accident classification (see Table 5-2) are: 1) those involving cranes or hoists or integral parts of cranes or hoists (boom, anchor hardware, etc.) falling and/or falling and causing injury; and 2) slippage in the lift mechanism of the crane or hoist which causes the load to fall or machine to jerk and result in injury.

The promptness survey responses indicated the types of equipment which most often are involved in structurally falling or failing hoists or cranes are (listed most to least frequent): overhead and monorail cranes; stacker cranes; boom and hydraulic boom truck cranes; trucks with boom winches; stationary cranes; electric hoists; chain hoists; and hand hoists. The objects which fall when cranes and hoists fail or fall are: booms and braces; hoists; cranes; crane handles; and hoist motors. For cranes whose hoist mechanism slip or jerk, the types of equipment involved are: chain hoists, overhead cranes, winches and roofing power hoists. The objects which fall as a result of crane slippage run a gamut from parts moved for assembly, to sling yokes, to cranes and crane parts; with no item of any frequency apparent. The industries most frequently having crane or hoist accidents similar to those above are: machinery manufacture, except electrical (especially construction machinery manufacture); primary metal industry (especially gray iron and steel foundries): fabricated metal products (especially fabricated structural metal products and iron and steel forging); and construction.

The causal factors the promptness reports and investigations indicated for the accidents in this classification were:

1) Poorly maintained hoist brakes.

2) Hoist anchor hooks and safety latches fail (hoist falls).

3) Gears slipping on chain hoists.

4) Brakes failing to hold loads, below hoist or cranes rated/capacity.

5) Hoist (crane) running ropes slipping off sheves, pulleys (jerk loads).

6) Lack of drive train guarding near emergency brake levers--result in operators making emergency moves getting caught in mechanical parts.

7) Maintenance or modifications being performed on crane booms, without blocking booms or relieving tension on support ropes.

8) Maintenance personnel omitting to replace or reset crane tracks or end stops and limit switches after service work.

9) Overloading cranes (boom cranes) and hydraulic boom failure.

10) Stacker cranes hanging up on jutting racks, pallets and falling.

11) Ice on hoist moving parts, rails--causing slippage.

12) Hoist trolley wheels bend--hoist falls below rated load weight loading.

13) Handles on come along hoists not well attached, falling or pulling out.

14) Electrical system failures cause hoist brakes to fail.

Interview Results--

The 58 comments made by workers which related to this classification of potential accidents are presented in Table 5-9. Many of these types of hazards (related to physical functioning of machines) may closely relate to causal factors in accidents and hazards discussed in parts A and B of this section: for this reason, much of the information in Tables 5-6 and 5-7 is related to the comments presented in Table 5-9.

TABLE 5-9

D. HAZARDS AND CONTROLS RELATED TO THE POSSIBLE MALFUNCTION, MISOPERATION OR FAILURE OF CRANES AND HOISTS.

I. HAZARDS PERTINENT TO MAINTAINING THE SMOOTH AND SECURE PHYSICAL FUNCTIONING OF CRANES AND HOISTS (27 comments).

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Cranes and hoists with physical faults can operate jerkily, fall from their support system, fail to respond to operator's controls as anticipated (increase load falling likelihood). -Repairs made to "get it working" or modifications to machinery made during repair may make future work on a machine difficult or impossible for other than personnel modifying crane or hoist. -Exposure to heat or vibrations can age hoist and crane cables and loosen bolts securing cranes and hoists to supports or rails resulting in an unexpected equipment failure.	-A system for operators to check out all basic functions on cranes and hoists, report any problems, and rapidly have these problems solved should be developed to cover all cranes and hoists. This is especially a problem for 2nd and 3rd shifts where support personnel are minimal. -Where possible function problems can't be rapidly repaired, alternative equipment should be available to make it unnecessary to use a defective crane or hoist. -Crane operators should regularly (daily) lubricate control levers and electrical contacts on crane controls to maintain their smooth operation. -Documentation should be kept on all repairs, modifications, usage problems reported, etc. for each piece of equipment, to facilitate rapid repair (or usage problems development). -Preventive maintenance schedules with adequately frequent inspection and replacement procedures should be developed to cover cranes and hoists in use in a plant. The amount of time between inspections and replacement should be determined by the amount of use and exposure to destructive elements to which the machine is subjected.	-No specific protective measures were indicated that deal with the above described hazards; other protective comments from Tables 6 and 7 probably apply.

II. HAZARDS ARISING FROM THE DESIGN AND FUNCTION OF CRANE AND HOIST CONTROLS, AND THE ABILITY OF THE OPERATOR OF THE MACHINE TO SAFELY OPERATE IT (17 comments).

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-When operators of cranes or hoists switch from one machine to another, their ability to smoothly and precisely operate the machine can be adversely affected by differences in the sensitivity of controls in different machines.	-Before using any crane or hoist for the first time during a shift, the operator should check out all the control functions of the machine so that he or she is aware of how the machine will react (as well as detecting any physical problems in a machine's function). -Machine brakes should be adjusted, serviced and frequently checked to make sure they are able to handle the weight of the loads the crane or hoist carries.	-See above comments.

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TABLE 5-9 Continued

-Pendant controlled hoists and cranes occasionally don't function consistently, buttons will stick, brakes are irregular, buttons won't work, and the machine will stick in one mode of operation (i.e. lifting or lowering). Operators of pendants also do not get a good sense of feel from the braking operation of crane trolleys or bridges. -Cab operated lever controls can operate roughly and cause loads to jerk. Some automatic electric brakes give little flexibility to the operator as far as amount of application (brakes can grab). -Limit switches on hoists or rail crane systems can fail to function on occasion, causing a possible equipment failure.	-Where operators of cranes or hoists detect irregularities in the smooth operation of their machine's controls, they should be reported and repaired quickly. -Pendant controls (buttons) require more time to smoothly handle loads than level controls since it is harder to smoothly start and stop loads with the buttons than the levers. Operators can lubricate levers and lever contacts to keep them working smoothly, no operator servicing can be done to prevent sporadic operation problems from developing in pendant buttons. -Unless physically connected to a crane, the operator cannot get good feeling (tactual feedback) of the action of brakes on the crane, hoist and load. This makes manipulation of loads from floor operated cranes more difficult. -Limit control switches should be regularly checked. They shouldn't be used as brakes in normal operations.	
III. HAZARDS RELATED TO THE SMOOTH AND SECURE FUNCTIONING OF CRANES AND HOISTS WHICH ARISE OUT OF THE OPERATIONS OF THE MACHINE (14 comments).		
Nature of Hazard	Measures Indicated to Prevent Hazards from Developing into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Locking trolley, bridge or hoist brakes can cause machines to skid, wearing the drum, rails, etc. of the machines. This can develop smooth and worn spots, flat spots, and gouges which will cause hoists and cranes to slip or jerk in their operation. This can also develop when one crane bumps another crane with its brakes on or not in a neutral control mode. -Overloading cranes can increase the wear on moving parts and metal fatigue in cranes and hoists.	-Operators of cranes and hoists should smoothly operate their machines, avoiding overloads or skidding which will accelerate wear on the parts of the machine. -By keeping loads low when moving them and maintaining a length of cable between the load and hoist or boom tip, some of the shocks and jerks in moving loads will be absorbed. -Hoists and boom tips should be centered above loads before lifting to avoid side loads on booms or running ropes. -When mobile cranes are set up for use, their outriggers should be placed on firm supports (not soft ground) and be fully extended. When long booms or other potentially unstable configurations are being used, experts in the set-up and support of mobile cranes should check the cranes set-up. Applicable load charts should be available to crane operators to avoid overloads.	-Operators of cranes should learn where worn spots are on crane rails so they can compensate for any slippage due to the rail wear by operation of the bridge controls. -(On small capacity mobile cranes) operators can sense the effect of an overload on the crane's balance and quickly, but with control, lower a too-heavy load. (Larger capacity cranes give less of this balance feedback to the operator.)

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TABLE 5-9 Continued

-Failure to center hoists above loads, jerking hoists, or side loading boom cranes can pull running ropes off of multiple rope hoist and pulley systems, or damage booms from side pull stresses. -Mobile cranes can tip below load rating capacity if they are not set up securely on a firm base.			

The comments made by workers fit into three general categories presented in Table 9: 1) those dealing with the maintenance of smooth and secure functioning of cranes and hoists, in order to insure safe load handling; 2) comments related to the ability of the operator of a crane or hoist to utilize his or her machines' controls to safely and smoothly handle loads with the machine; and 3) those comments made by workers regarding procedures involved in the operation of cranes and hoists which can or do affect the secure and smooth operations of the machine. Where a number of causal and descriptive factors in the accident analysis indicated that come along and chain type hoists were involved in some accidents in this classification, these types of equipment were not in use in the plants we visited.

The preventive measures workers indicated mainly concerned activities which should be undertaken to maintain the smooth and secure function of cranes and hoists; or where the design of some function of a crane or hoist adversely affected the operator's ability to smoothly operate the machine, comments emphasized what equipment or operations changes might remedy those problems. The comments of workers related to maintenance indicated the need for an effective inspection, report and repair program to insure that cranes and hoists are kept in top operating condition. The attitudes expressed indicated that machine operators should be responsible for daily evaluation of their machine's controls function (both to detect the development of problems and to be familiar with controls variations) and for the routine lubrication of moving control parts. A more formal maintenance program to detect and alleviate problems in major mechanical systems before their adverse effects made safe machine operations difficult, and an effectively frequent inspection and replacement program for crane or hoist parts subject to excess wear or breakdown was also indicated.

Problems arising out of the design or functional operation of machines centered around chronic operation problems workers noted are involved with the use of pendant controls and, to a lesser degree, level controls, and operator's practices which have the potential of causing damage to the smooth functioning of their machines. The thrust of the preventive measures indicated worker's suggestions for alleviating these problems.

E. HAZARDS AND ACCIDENTS COMING FROM REQUIREMENTS FOR MANUAL EXERTION IN THE HANDLING OF LOADS WITH CRANES AND HOISTS

The hazards and accidents in this classification are those which arise from workers becoming manually involved in the operation of materials handling with cranes and hoists. These factors generally involved potential overexertion in manhandling loads or crane or hoist equipment and, to a lesser degree, floor workers involved with cranes or hoists who are subject to tripping injuries from obstructing objects.

Accident Analysis Results

This accident classification accounts for 8-1/2% of the accidents selected from the 1974 employe promptness of payment survey which implicated cranes and hoists as the principal causal source in the accident reported. Only one of this type of accident was investigated and this accounted for only 1-1/4% of the accident inspections. The accidents in this category generally indicated type codings of overexertion in handling or operating a crane or hoist, or a fall on the same level over some sort of object. Accident type coding of falls to the same level accounted for 2-1/2% of the cases whose source was coded as cranes or hoists on the Worker's Compensation file from 1972 to 1975; and 2-1/4 of the Worker's Compensation costs. For accidents type coded overexertion and source coded as cranes or hoists, the percentage of frequency was 9-1/2%, and the cost 5.25%.

Three categories of accidents were found for this classification (see Table 5-2): 1) Accidents involving overexertion in the operation (primarily moving loads) of cranes or hoists; 2) the operator of a crane or hoist (generally floor operated) injured by an object not part of the crane or hoist, while operating the equipment (generally falling or tripping over the object): and 3) operators maneuvering materials to load or hook them to a crane or hoist and receiving an injury (generally an overexertion case).

The most frequently implicated types of equipment involved in these incidents are (listed most to least frequent): overhead cranes; magnet cranes; hydraulic cranes and hoists; chain hoists; hand hoists; and winches. The types of materials being moved most often are: steel loads (piles of tubing, plates, forgings, beams, castings, etc.); various containers (barrels of beer, drums of chemicals, buckets of plastic, etc.); rolls of paper; and small machines or parts of machinery. The industrial classifications which show up most repeatedly for these cases are: fabricated metal products, especially iron and steel forging; primary metal industries, especially steel pipe and tubing and gray iron foundries; machinery manufacture, except electrical; transportation equipment manufacture; trucking and warehousing; and paper and allied products.

The causal information related to the falls accidents was:

1. Workers falling over some obstructing object while trying to move, attach or remove objects from cranes or hoists. The objects tripped over (angle iron, 2 x 4's, forgings, roller stand, oil spots) tend to indicate that these cases involved a lack of maintenance of clear passageways where cranes or hoists are operated.

The causal information related to overexertion accidents were:

1. Pulling on the crane or hoist to either lift or move the load.

2. Applying muscle to a hoist or crane which operates roughly or hangs up (on rail welds for example).

3. Trying to push loads beyond the movement limits of the hoist or crane, to put load on a worktable or platform.

4. Trying to manipulate or lift loads to aid in their attachment to hoists or cranes.

5. Workers forced to stand in an awkward position to manipulate, hook or unhook loads.

The one key element which seemed to run through the overexertion accidents was the fact that the loads moved were apparently not extremely heavy. This may have encouraged workers to try to manipulate these loads manually, rather than making more precise use of available hoists or cranes as would be the procedure with heavier loads.

Interview Results

Workers made 29 comments which indicated hazards or controls related to this classification of accident type. This is somewhat short of the number of comments which would have been expected, were workers' comments for this classification in the same proportion to accident frequency.

When asked about manual exertion hazards related to hoist and crane use, workers frequently indicated they felt no such hazards existed. It may be that one worker, who indicated that he was too old to be worried about showing how strong he was by lifting heavy objects, and now got help lifting heavy items, may have hit the nail on the head as to why many overextertion injuries develop. Another problem with this type of injury, is that over-exertions (sprains, strains and back problems) often develop from repeated chronic stresses rather than one time acute traumas like most of the crane and hoist accidents we have previously mentioned.

The comments made by workers are summarized in Table 5-10. These comments fell into three categories of manual exertion involvement hazards: 1) those arising out of the physical requirements involved in the utilization of cranes and hoists to handle materials (moving loads, setting hitches, selecting slings, etc.); 2) design and functional limitations of cranes and hoists which can add to the likelihood of manual exertion involvement injury; and 3) hazards coming from obstructions to the uncluttered movement of workers on the work floor using cranes and hoists.

The preventive measures workers indicated they should carry out to cope with these hazards involved: using mechanized methods (hoists and cranes) to substitute for manual lifting where possible or obtain help handling heavy objects; and the exercise of caution while climbing on or around large objects. The maintenance of good housekeeping around their work stations was another preventive measure workers felt could be generally dealt with at the work site.

Preventive measures which workers felt they had little or limited ability to exercise without management support were: the proper design of crane cabs and pendant control attachments; having the facilities at hand to obtain help from other workers when they needed it; and maintaining sufficient storage and room around work sites to be able to work without obstruction.

TABLE 5-10 **E. HAZARDS AND CONTROLS COMING OUT OF MANUAL EXERTIONS INVOLVED IN HANDLING LOADS WITH CRANES AND HOISTS**

I. HAZARDS OF MANUAL INVOLVEMENT DEVELOPING FROM THE PHYSICAL REQUIREMENTS OF USING CRANES AND HOISTS TO HANDLE MATERIALS (14 comments).

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Manually having to push and turn or position loads while lifted poses the possibility of sprains or strains. The possibility of an overexertion injury is also present when a hitcher or pendant crane operator must hold or lift a load in order to keep it balanced. -Workers who have or choose to lift loads on other significantly heavy items to be used in crane and hoist materials handling. This includes lifting heavy slings, manually positioning loads for lifting and having to do manual work alone--usually done with assistance. -Workers having to climb on and off loads in order to properly hitch them (climbing onto railroad cars, getting in and out of crane cabs, etc.).	-Where possible, hoists or cranes should be used to do manual lifting tasks. In regards to this, however, workers indicated it is often much easier to manually maneuver heavy items than to get a hoist system (gantry crane, jib crane or bridge crane) and proper attachments to handle items. -When anything heavy needs to be manually lifted, get help from another worker to lift it - forget about trying to show off your strength. -When climbing on loads, etc., watch out for oil on shoes or a piece of the load.	-No protective measures mentioned.

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TABLE 5-10 Continued

II. EQUIPMENT DESIGN AND FUNCTION LIMITATIONS CONTRIBUTING TO THE LIKELIHOOD OF MANUAL EXERTION - INVOLVEMENT INJURIES (8 comments)

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Pendant controlled hoists and cranes whose pendant cables are too short requiring operators to stretch themselves out to see around or maneuver bulky loads. -Pendant crane operators who have to climb instable ladders or stools in order to see where they are moving their loads. -Cab operators of cranes having to lean or stretch out over cab of the crane to see loads below the crane cab's floor. -Virbrations or bumps from travelling in mobile cranes or from the jerks of normal crane operations can create a sore back--especially where the operator's seat isn't well padded.	-Pendant controls should have control cables long enough to allow operators to move around loads as necessary, without stretching themselves or cord. -Where visibility around load or the load's destination is prohibitive for an operator on the floor, he or she should be elevated to a cab or some stable platform. -Crane cabs which have to lift items below the cabs should have windows or vision holes in the cab's floor. -Seats for crane operators should provide padding from small bumps and jerks, and provide lower back support.	-No protective measures mentioned.

III. HAZARDS INVOLVING WORKPATH OBSTRUCTIONS WHICH MAY OBSTRUCT OR TRIP WORKERS INVOLVED IN CRANE OR HOIST OPERATIONS ON THE WORK FLOOR (7 comments).

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Excessive floor space taken up by increased production, debris around a hoist station, slings left on floor, unorganized storage, etc. can block or partially prohibit the free movement of a worker concentrating on a raised load, or trying to escape a falling load.	-Housekeeping should be maintained in areas where hoist or crane operations are staged. -Slings and other materials used in crane and hoist operations should be stored out of traffic areas when not being used. -Work areas should be kept large enough to allow workers to perform their tasks without bumping into the items around them when working with cranes and hoists.	-Workers should be sure they have a clear path of egress to get away from a load if a problem develops.

F. HAZARDS AND ACCIDENTS ARISING FROM: WORKING ON OR AROUND CRANE HARDWARE, ENTERING OR LEAVING CRANE CABS AND MAINTENANCE OPERATIONS

The accidents and worker comments in this classification are a conglomeration of reports indicating the danger of falls or hazards of working at heights which are associated with normal crane operations or maintenance operations. These are summarized below.

Accident Analysis Results

This classification is made up of two accident classifications from Table 5-2. These are Numbers VI and VII. These two classifications are combined for analysis because many elements of the accidents which constitute them are similar. The first classification, injuries from operating on or around cranes or crane hardware, accounts for 5-3/4% of the crane and hoist cases selected from the promptness survey. Four percent of the accident investigations pertained to this classification of accidents. The second classification, accidents resulting from maintenance operations not covered in other classifications, represents only 3-1/2% of the promptness survey sample; and 4% of the accident investigations. The codes corresponding to falls from elevation with crane or hoist source codes account for less than 1% of the frequency and cost of crane and hoist coded cases from the Worker's Compensation file. The bulk of the cases analyzed from the promptness survey were source coded to sources other than cranes or hoists on the Worker's Compensation file.

The categories of accidents that went into these classifications are:

1) Workers falling or stepping off a crane or hoist.
2) Workers injured climbing into a crane, and workers injured falling from overhead crane rails.
3) Workers injured setting up or disassembling a crane or hoist.
4) Workers injured replacing a cable on a crane (mostly falls).

The principal types of cranes and hoists involved in these accident classifications are (listed most to least frequent): mobile cranes (truck cranes, crawler cranes, and other portable boom type cranes); overhead cranes; and to a lesser degree, chain hoists, and other small materials hoists. The industries reporting accidents of these types primarily are: construction; wholesale trade--durable goods; primary metal industries; and tire and inner tube manufacture.

The causal factors involved in the accidents reported in the promptness survey are:

1) Lifting hoists and other parts of equipment into position causing strains.
2) Dropping apparatus while installing it and falling.
3) Walking or working on slippery surfaces--ice, snow, grease and oil.
4) Working on unstable maintenance platforms.
5) Feet catching in parts while working.
6) Fingers getting caught between trolley wheels and rails.

7) Coming into contact with power lines while working on top of a crane boom.

Interview Results--

Workers interviewed indicated hazards related to this classification which dealt primarily with considerations for safety when they were engaged in maintenance operations. The twenty comments summarized in Table 5-11 were given by five full-time maintenance personnel interviewed in two of the plants we visited.

All of these comments related to the physical hazards which maintenance operations exposed workers to, especially those arising from working on the bridges of out-of-service overhead cranes. For the most part, these hazards resulted from the exposure to energized power contacts, to heights, or to collisions from other cranes operating in the same bay as an out-of-service crane being maintenanced. Workers indicated that given the proper warning or lockout procedures, or work platforms, these hazards could be controlled.

G. OTHER HAZARDS AND ACCIDENTS NOT PREVIOUSLY COVERED

A few of the accidents reported in the promptness survey and a number of accident investigations, primarily dealing with unintentional contact with overhead power lines in boom crane operations, were not covered by the preceding categorization of accident classifications. In addition a few of the comments made by workers interviewed during the field investigations, primarily regarding general comments made about safe hoisting operations or job stresses involved in the operation of cranes or hoists didn't fit properly into any of the classifications previously discussed. These accident types and comments are presented below.

Accident Data Analysis--

These remaining accident categories, mainly derived from the promptness survey responses, accounted for only a very small (4-3/4%) portion of the employe promptness reports analyzed. In more than half of these cases, no determination of the type of accident involved could be made. Of the remaining cases:

1) two involved injuries produced by the design of the crane operator's cab controls (foot strain from brake pedal, and shoulder and back strain resulting from repair and relocation of the crane operator's seat).

2) four cases concerned workers working in the proximity of a crane who were injured bumping into a stationary crane (one case indicated that the crane was parked in the wrong location).

The final classification of accidents only had three cases reported on the promptness survey. This is because fatalities tell no tales! These are cases where workers get injured, and quite often killed as a result of a

TABLE 5-11 F. INDICATED BY WORKERS PRODUCED BY THE PHYSICAL ACTIVITIES REQUIRED IN WORKING AROUND CRANES

I. HAZARDS TO PHYSICAL SAFETY IN CRANE MAINTENANCE OPERATIONS (20 comments)

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Workers on out of service cranes performing repairs are vulnerable to being struck by cranes still in operation in the same crane bay. -Fall hazards exist for workers working on or around crane bridges to perform repairs, or to listen to and observe crane machinery to diagnose operations problems. -Either because of the inability to shut off all power to a crane bay (shutting down all the cranes in that bay (nail)), or poor plant lock-out procedures; maintenance personnel are sometimes exposed to live power sources (mainly bridge travel power contacts not usually designed to disconnect to single cranes in multiple crane bays). -Maintenance workers could be involved in caught-in moving parts injuries while involved in crane maintenance operations. -Mobile crane operators performing routine maintenance on cranes have to climb around crane.	-Warning devices (lights) should be used to alert operating cranes of out of service cranes; and a strict rule for operating cranes to stay clear of out of service cranes flashing these devices should be enforced. -Use support boards or other devices to provide a platform for working on the bridges of overhead cranes. -Use available lock-out systems when doing work on cranes outside of the crane cab. When extensive work needs to be done on motors or bridge drive systems, shutting down power to the entire crane bay should be considered. -Hoist drums, running ropes, and other parts which may move during maintenance should be locked or blocked in place. -Maintenance workers shouldn't wear glasses or loose items not secured to their person as they may instinctively grab for these items should they fall, possibly resulting in a fall or caught-in accident. -Mobile cranes should have non-slip grates or walkways to allow safe footing for maintenance on machinery. -The best preventive to maintenance hazards is to minimize the time machines must be worked on. Regular lubrication of controls and rails will extend the time machines remain trouble-free. Good records on equipment will speed repairs.	-No protective measures indicated.

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crane coming into contact with overhead or other power lines. Seventeen cases, or 22-1/4%, of the accident investigations involved this type of accident. The Worker's Compensation file indicates 37 cases of cranes and hoists (one electric hoist) contacting electrical power; this is 2-1/4% of the accident totals for cases coded as cranes or hoists. The Worker's Compensation cost of these accidents was $244,303 or 17-1/4% of the cost of crane and hoist accidents. Of these accidents, 19 cases involved fatal injuries.

The overwhelming number of electrical contact accidents involved boom type cranes. Many of these incidents took place at or around construction sites; however, a fair proportion of the cases occurred in the yards of industrial plants. The main industry suffering this type of accident was the construction industry; as well as wholesale scrap, waste metal processing, and electric and sanitation work to a lesser degree. These accidents did not generally injure the operators of cranes, but rather hook up and guide men outside of the crane structure.

The causal factors most important in these cases involved:

1. Working in too close proximity to live overhead high voltage lines.

2. Hitchers and guide men holding onto guide lines and crane attachments when booms contacted power lines.

3. Operators of cranes not being aware of the location of power lines, or the proximity of their booms to power lines.

4. Not disconnecting and grounding power lines when working in close proximity to them.

These cases are discussed in more detail in the discussion of crane fatalities in this section, and in the segment on mobile cranes in the supplementary report to this chapter (Gottlieb 1978).

Interview Results--

The remaining comments from worker's interviews are presented in Table 5-12. These comments on hazards in the use of cranes and hoists related to the personality attributes crane operators and, to a lesser degree, hitchers need to possess to safely operate their machines. Other hazards were noted by crane operators who indicated they were exposed to high levels of some toxic substances, working above certain operations in foundries. These comments are expanded upon in Table 12.

CRANE USE FATALITIES

The Wisconsin Worker's Compensation Case History File shows 30 incidents where cranes or hoists were indicated as the main source of injury in fatal accidents from 1971 through 1975. An additional two cases involving a fatality were not source coded as crane accidents, but according to their

TABLE 5-12

G. OTHER WORKER COMMENTS NOT PREVIOUSLY DISCUSSED

I. SAFETY ELEMENTS IN CRANE OPERATIONS ASSOCIATED WITH BEHAVIORAL AND PERSONALITY ATTRIBUTES OF CRANE OPERATORS AND HITCHERS (13 comments)

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Operators, hitchers and signal personnel have to communicate effectively for operations to run smoothly. A number of factors may interfere with the effectiveness of this communication: (1) inexperienced hitchers just starting on the job; (2) lack of standardized hand signals; (3) new pairings of operators and hitchers, from shifts or work changes; and (4) more than one hitcher of a group giving signals to a crane operator. -Operators of cranes need to have skills and qualities in their personality to safely operate cranes: (1) new operators need thorough training; (2) larger, more complex cranes require more finesse to run safely; and (3) crane operators can't work safely if they get nervous, or who can't or don't pay attention to their task.	-Operators and the hitchers they work with should be sure they have their signals straight. This is especially necessary to get straight when unfamiliar people are working together, or for hitchers and operators who don't get along well off the job. -Crane operators just starting their job, or working a new crane with new loads, surroundings, etc. should be trained and checked to make sure they have adequate training, skills and sensory capacity (e.g. depth perception) to handle the job. -Only people with stable personalities should operate cranes.	-No protective measures indicated.

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TABLE 5-12 Continued

II. PHYSICAL AND PSYCHOLOGICAL STRESSES INDICATED FROM JOB REQUIREMENTS AND TOXIC EXPOSURES (10 comments)

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-Operators of cranes are sometimes pressured to work faster than they feel is safe from: (1) increased production scheduling; and (2) incentive paid workers being serviced by crane operators, clamoring for the use of the crane. -Crane operators, especially those in open cabs working in foundry type operations, are often exposed to toxic fumes (lead) and dust, often impairing immediate alertness and deteriorating long-term health.	-Crane operators shouldn't get frazzled or allow themselves to be rushed or to hurry operations to do them faster than what they feel is safe. -When production periodically gets heavy, the number of hours of production should be increased, instead of trying to rush work. -Where cab operators are exposed to airborn contaminants, the cabs on their cranes should be enclosed and supplied with filtered air. A less attractive preventive measure is the use of respirators or dust masks. These may not be as effective if workers are required to remove respirators or masks to talk to floor workers, or open windows for the same purpose.	-No protective measures indicated

III. OTHER COMMENTS (2 comments)

Nature of Hazard	Measures Indicated to Prevent Hazards from Developing Into Accidents	Measures Indicated to Protect Against Injury if Hazard Develops
-On some older bridge cranes, some of the electrical contacts along the inside of the bridge rail are exposed. Raised and swinging crane hooks could contact these, possibly exposing someone to an electrocution hazard. -The metal capacity tags on chain slings can get tangled in the chains and snap off, fly and possibly strike workers, and no longer provide load capacity information.	-Older cranes should have their contacts covered and shielded like the newer cranes do. -The company with the tag problem was granted a variance to add an oversized link to one chain arm of a sling and their link was stamped with the capacity information.	-No protective measures indicated.

accident investigations, cranes or crane operations were critical factors in these incidents. The principal categories of fatality due to crane operations are: (two early 1976 cases are included).

1. Contact with overhead power lines through cranes (cables and booms), 22 cases (this includes one of the cases not source coded as crane or hoist).

2. Being struck by some object falling from a crane or hoist, or by a falling hoist, 6 cases.

3. Being struck by some moving part of a crane or hoist, 3 cases (including one of the cases not source coded as a crane or hoist).

4. One case each of: a worker killed falling with equipment; a pedestrian struck by a truck crane; and an overhead crane contacting some electrically energized parts.

The probable causal factors for these types of accidents are discussed in the following analysis.

The most common victims of fatal crane accidents are: Construction general laborers (8 cases); truck drivers (8 cases); other general laborers (3 cases); and 2 cases each for foremen, roofers, electric power linemen and maintenance operatives. None of the inspected cases indicated that a man inside of the crane cab was the victim of any of these fatal accidents. The primary victims of all of these incidents were hookers, hitchers, guide men, or crane operators operating the equipment with pendant or other remote controls.

For the nonelectrocution fatal cases which were inspected: two involved cables coming loose from their attachments; one was caused when a crane boom and attached magnet resting on a pile of scrap metal slipped and swung free to crush a man in a truck cab; another was the result of a plate clamp and plate slipping off their hook when the pressure slacked as the load was set down, falling on an employe; and a fatality was caused by a jerky roofing hoist working free of its anchor materials and falling.

The power line contact electrocution fatalities which were inspected all involved boom or derrick cranes. The key illuminating factors as to the causative natures of these accidents mainly point toward some disregard for a known hazardous situation (contact with overhead energized power lines). In three of the investigations of crane electrocutions, large permanent warning signs on the cranes, and constant management warnings related to working in the proximity of power lines lead the inspectors to conclude that no violation of standards requiring proper distance from power lines could be attributed to the employer. In another five investigated crane electrocutions, knowledge of the proximity and danger of power lines was testified to by various of the principals in the accidents; however, in all these cases, the involved workers either felt they could avoid contacting the lines during the fatal operation or, despite the use of one or more look outs, came into contact with the proximate power lines during the operations. Only one inspected case indicated that the operator, in this case also the deceased, operating the crane from outside the truck, may not have been informed of the hazard presented by overhead power lines. The remaining crane electrocution inspections do not provide clear enough information to draw any inferences.

Overall the crane fatalities seem to reflect similar accident patterns as the rest of the crane accidents. The most outstanding source of crane fatalities come from contacting overhead wires while the crane is operating. This pattern of accident causality is similar to those accidents involving moving loads or cranes striking objects in their path (classification 2). Most of the electrocutions inspected seemed, in retrospect, easily avoidable if a few simple precautions had been taken prior to the commencement of the operation. The remaining fatalities appear to be characteristic crane accidents where someone was in the wrong place at the wrong time.

IV. THE HUMAN FACTORS DYNAMICS IN OVERHEAD LIFTING SAFETY

INTRODUCTION

What Causes Accidents

In a recent study of accident investigations (Hagglund, 1976) it was found that 54% of 257 investigated accidents implicated some factor; primarily physical ("unsafe condition") as the principal accident cause. The purpose of the above study was to question the claims of numerous safety professionals and organizations arising from a study of accident causation by Heinrich (1959) that 75-95% of industrial accidents are caused by "unsafe acts". This latter statistic has been interpreted by some industrial management personnel as indicating that worker's unsafe behaviors are responsible for the bulk of industrial injuries, and, therefore, expenditures for improving safety are of little value.*

For the purpose of preventing accidents and protecting against serious injury, that notion of the unsafe act or unsafe condition is of little value. As Hagglund concludes at the end of his study, "It is more likely that accidents are caused by interactions of a variety of complex events and factors" (1976). The point is not that unsafe acts or unsafe conditions don't play a role in causing accidents in overhead lifting, but rather that numerous physical and behavioral factors may combine to cause an accident or to create a hazardous situation where the potential for an accident exists.

How Do You Avoid Accidents

Once an accident occurs, the system to insure worker safety has failed. Any post-mortem analysis, at best, serves to point out areas where attention is needed; and seldom does more than place blame and assess punishment. Unfortunately, the legal system attached to industrial accidents encourages blame assessment making an accurate attempt at causal analysis almost impossible. The proper time to control accidents is before they occur by regulating or eliminating the hazards which can lead to accidents.

The purpose of studying crane and hoist use safety is to point out the areas where hazards are found to exist, and indicate what means are used or what further efforts are needed to manage these hazards.

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*A current series of NIOSH studies (Cohen, Smith and Cohen, 1975; Smith, Cohen, Cohen and Cleveland, 1978; and Cleveland, Cohen, Cohen and Smith (in press)) have shown that it is the qualitative nature, rather than just the quantity, of industrial safety programs which determine their effectiveness.

The Hazards of Using Cranes and Hoists

Section III of this chapter details the factors found to be involved in the causation of accidents related to the use of cranes or hoists, and the opinions of what workers and managers involved with crane or hoist use consider to be the hazards related to these overhead lifting problems. This information, summarized in Tables 5-1 thru 5-12, indicates five general situations where the use of cranes or hoists are likely to present hazards which can and do lead to worker injuries. Hazards related to these types of situations include:

1. The attachment devices used to secure loads to cranes and hoists fail to hold the load when lifted, resulting in the load falling.
2. The movement of the crane or hoist and/or the lifted load leads to a collision with some other object or person.
3. Load hitchers, signal personnel or floor located operators of cranes or hoists (and other floor traffic) getting injured while attaching a load or while participating in a load's movement with a crane or hoist.
4. While lifting or moving loads some structural or mechanical component of a crane or hoist may fail to operate as expected or collapse.
5. Crane operators or maintenance personnel working on or around cranes or crane structures risk injury, primarily from falls or caught-in injuries.

While these five types of situations were found to be sufficient in describing the range of possible conditions from which crane or hoist accidents can arise, the hazards and associated controls indicated by the field study often act across these situational categories. It was found that the comments of workers and managers involved in the use, manufacture and distribution of cranes and hoists indicated four systems of physical and behavioral elements where attention to hazard control was essential to safe overhead lifting operations. These four control systems are those encompassing:

A. The factors which are principally behavioral that are involved in the operation of crane or hoist systems;
B. The principally behavioral factors involved in load attachment and human involvement in load handling support of loads handled by cranes or hoists;
C. The principally physical and behavioral aspects of the loads to be handled by cranes and hoists and the attachment systems for these loads; and
D. The principally physical aspects of the performance and mechanical limitations in the design and function of crane or hoist systems.

These four control systems and their critical interactions encompass the dynamic elements involved in handling materials with cranes or hoists. The balance of this chapter will focus on the human factors components of these systems which were indicated by our study of crane and hoist use, and were found to be essential to safe overhead materials handling. For the sake of brevity, these discussions will avoid much of the operations-related detail which our research found important in crane and hoist use safety. An emphasis will be placed on defining those factors which emerged as the most crucial to safe crane and hoist use. Readers who are interested in a more detailed discussion of of these various factors are directed to a supplementary report on crane and hoist use (Gottlieb, et al, 1978) and to the various references and standards noted in the following discussions.

A. BEHAVIORAL FACTORS IN THE OPERATION OF CRANES AND HOISTS

More than any other single factor, the way in which a crane or hoist is operated is central to safety in overhead materials handling. This was an almost universal constant in our discussion with anyone associated with the use of cranes and hoists. Crane operators who were perceived as "doing a good job" were considered an essential asset in insuring crane or hoist use safety. Likewise, where some problem was perceived regarding the way in which a crane was operated, significant safety hazards were indicated as being associated with the crane or hoist operations. If the summary of worker's comments presented in Tables 6 - 12 are studied, the role crane (and hoist) operations play in relation to all of the possible sources of overhead lifting accidents is pervasive. At least one aspect of each hazard indicated is either defined by some component of crane operations, or sees crane operation as an important preventive factor in the control of overhead lifting hazards.

Other factors involved in overhead lifting such as the function of crane or hoisting machinery, and the nature and function of load attachment systems, are essential to safe crane and hoist use. However, while these factors are seen as necessary to lifting safety, different elements of crane operations are able to have both positive or negative effects on the safety aspects of these other factors. On the other hand, functions of lifting machines or load attachment systems are often seen as factors which, if inadequate, adversely affect crane or hoist operations, but which cannot compensate for insufficient crane operation.

The clearest example of the importance of crane or hoist operations to the safety of an overhead materials handling situation, involved an engine hoist system found in a small foreign car repair shop. This "hoist" consisted of an alloy chain draped over a ceiling I-beam, and used a ratchet type chain tightener to affect its hoisting action. The mechanic who pointed this system out indicated the need for being very careful when using this homemade hoist system. Fortunately no injury, to anyone's knowledge, has ever resulted from the use of this hoist. Here a potentially hazardous piece of equipment has, until now, been used safely primarily through the vigilance of the hoist's operators. It is interesting that, according to current OSHA standards, a hoisting device such as the one described above probably is in general compliance with the standards. This will be discussed at greater length at the end of Part D of this section.

Factors in Crane and Hoist Operations Controlled by Operators

The crane or hoist operator is responsible for a variety of factors in the process of safely handling loads in overhead lifting. Many of these arise from the integral involvement of the crane operator in the processes of attaching, lifting and moving loads, and are detailed in Tables 5-6 and 5-12. Below is a list of the principal factors which crane or hoist operators indicated as their responsibilities in safe overhead lifting.

- Selecting and avoiding traffic and fixed obstacles in a lifted load's travel path.
- Checking the security and capacity of a load's attachment before lifting and travelling with the load.
- Making sure hitching or signal personnel are aware of a load being lifted or moved, and are clear of the load when it is lifted.
- Making sure the hoist mechanism of a crane is centered above a load and the load hitch is balanced to avoid the load swinging when it is lifted.
- Making smooth movements from one dimension of load movement to another to insure loads don't jerk and possibly fall.
- Determining that the weight of a load item to be lifted is within the structural and stability limitations of the crane or hoist being used (especially in mobile crane operation).
- Inspecting and testing crane and hoist operating systems including transport, limit switch, controls, hoist ropes and chains, and brake functions.
- Reporting problems in equipment structure or function for repair.
- Performing routine and minor lubrication, maintenance, or repair on cranes and hoists.

The degree of skill required of each crane or hoist operator to perform the above tasks varies in relation to the complexity of the crane or hoist used, the type of load handled, the nature of the load movements to be made (does the load need to be rotated or turned, or just transported), and the location of the crane or hoist's operating station relative to the load and its path. While some of these factors are beyond the control of the crane operator, a significant amount of safety in overhead lifting is determined by the skills and attentions which crane and hoist operators exert in their job tasks.

Crane and hoist operators, because of their close and constant relationship to the operation of their machines, are in an excellent position to routinely monitor and detect problems in the machine's functioning, and to perform minor maintenance on the mechanisms of the machine. The OSHA standards for Overhead and Gantry Cranes (1910.179) and for Crawler, Locomotive and Truck Cranes (1910.180) specify various operational components of these machines which should be frequently inspected. Most of the industrial users of cranes we visited made these frequent inspections a part of the crane operator's responsibility. Periodic inspections of the major mechanisms of the crane usually involve the crane operator and a crane maintenance specialist. Crane operators usually are expected to perform routine lubrication of crane controls, and to check and service other crane lubricant levels.

Prior to the task of lifting and moving a load with a crane or hoist, it was noted by a number of crane operators that they should select the pathway for moving the load. As part of this path selection, they try to note any possible obstacles which the load could hit or which might block the operator's view of the load or possible traffic below the load. Where some vision obstacle exists which a crane operator cannot avoid, crane operators indicated that they try to arrange to have their hitchers or signal persons signal them as to whether the obscured area is clear of traffic and safe to move the load through.

Another pre-lift task pointed out by crane operators is to maintain clear communications with their hitching and signal personnel. This communication is necessary both to make sure that the operator and load hitcher are satisfied with the security of the load's attachment, and to insure that the hitcher is prepared for the load's being lifted. This latter point, the crane operator making certain that hitchers are clear of a load which is about to be lifted and aware of its impending movement, is necessary to avoid the hitcher getting injured by getting caught-in loads and slings being lifted, or pinned or struck by a swinging load (Table 5-7 and 5-8).

While all crane and hoist operators have to be concerned with lifting loads of weights within the capacity of their hoisting machines and the load attachment system used, mobile crane operators need to be more cautious in this regard. Because the stability or structural lifting capacity of these machines varies with the length of the crane boom, boom angle, the support base of the machine (on outriggers or on rubber), and which part of the crane base a load is swung over (different stability and capacity when the load is lifted over the side of the crane or the back of the crane). As a result of their mobility and changing stability (related to lifting capacities), mobile cranes require attention to a number of factors related to load handling safety which operators of fixed site cranes and hoists don't have to contend with. A more detailed discussion of some of these factors which are the concern of mobile crane users and operators are presented in a two-volume series on crane operations and rigging in construction (Dickie, 1975), and in the supplementary report to this chapter mentioned previously (Gottlieb, 1978).

Safe operation of a crane or hoist while a load is being lifted or transported demands that the crane or hoist operator must continue to pay attention to a number of factors related to overhead materials handling safety, according to comments made by workers involved in these operations. Crane operators must keep conscious of the area around a moving load in order to avoid moving raised loads over or into people or traffic around the load. As previously mentioned, maintaining clear communications between the operator and hitching and signal personnel is important to the safe attachment and lifting of loads. It is also important for crane or hoist operators to keep track of these workers to avoid injuring them with the moving load. It was noted by a number of crane operators that difficulties often arise from workers on the floor not immediately involved in moving the load who move, unknowingly, into the area of the load's path. Since these workers aren't aware of a load's presence, crane operators indicated that it is their responsibility to avoid moving loads into the vicinity of these workers and to try to alert them to the loads presence by using the crane's warning device (horn or bell). Most crane operators expressing an opinion on the use of warning devices felt they should be used only when needed to alert workers who seem unaware of a load's presence.*

<u>The OSHA Standards</u> related to crane and hoist use include some general listings of procedures to be observed in handling loads with cranes (1910.179(n), 1910.180(h)). These standards provide what amounts to a "do's and don'ts" checklist for safe crane and hoist operations. While the provisions contained in these standards address many of the factors the crane and hoist operators we interviewed indicated as important for safe overhead lifting, the general provisions of these standards are nowhere required to be transmitted to workers designated to operate cranes or hoists. The development of these load handling standards and the crane and hoist inspection standards discussed previously, into a checklift or training presentation for crane or hoist operators might improve the effectiveness of these standards and overall safety in crane or hoist use.

Another standard of significance to crane operations and crane-

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*Some pendant crane operators complained of not having control of their crane's warning devices from their control box. Many of these crane's warning bells sound automatically when the crane starts to move; workers felt this reduced the warning device's effectiveness.

use accident prevention is OSHA Standard 1910.180(j). This standard addresses certain operational considerations important to mobile crane use near electric power lines. As indicated in the discussion of fatalities related to crane and hoist use, contact with overhead powerlines is the most frequent causal factor in fatal crane accidents. Because of the possible serious consequences of powerline contact, crane operators whose cranes may come close to these hazards should be well aware of these standards.

Factors in Crane and Hoist Operations Beyond the Control of the Operator

The crane or hoist operator, while controlling the functions of his machine in load handling, is in turn affected by the extent of control he is able to exercise by conditions beyond his immediate control. The factors of this sort which were uncovered by this study included:

- The nature of the crane or hoist machine, it's controls design and operation, and the location of the operator;
- The types of loads, load handling and attachment systems for these loads, and the personnel who work with the operator to hitch and move loads;
- The layout of the workplace within which the crane or hoist operator has to perform his load handling tasks;
- The pace of work required of the crane or hoist operator to meet the demands of production, or of the workers the operator serves; and
- Environmental stressors which can have an adverse effect on the crane or hoist operator's senses, alertness or health.

These above factors, which are created or alleviated somewhat by the way in which management or supervisory personnel set up work and production, can have a significant impact on safety in crane operations. The observations, comments by interviewed workers and supporting literature related to these above factors, will be summarized in the following discussions.

The design of the operating systems of cranes or hoists was indicated as having an effect on the machine operator's abilities to perform various tasks for which they are responsible in overhead materials handling. The location of the crane operator's control station, and the view and control of the load his location affords him, is one significant factor related to the design of lifting equipment.

A number of floor crane operators (pendant operated cranes) complained of problems related to vision around large-sized loads they have to move. Another complaint of pendant crane or hoist operators related to difficulties they experience manually maneuvering large or bulky loads while still having to keep a hold on their pendant control boxes. This is particularly a problem when the cables on the pendant controls are short, restricting the movements of the operator. As a result of these limitations, extra signal personnel to relay information on blind spots to floor crane operators; crane or hoist operators having to assume contorted or dangerous body positions in order to see around or position loads; and crane operators having to climb ladders or get dangerously close to their moving loads; are all procedures floor crane or hoist operators indicated or complained of in relation to safely moving large and bulky loads.

Mobile crane operators often suffer from a lack of clear visual communication with their loads or load handlers. In situations where loads are lifted to great heights or over visually obstructive barriers, crane operators have to rely on signals relayed from the load's site or telephone communications from a signal person near the load.

Cab located overhead crane operators indicated that their view of some loads, primarily those located directly below the crane cab, was often obstructed by metal plates in the cab's walls and floor. Some crane operators found it necessary to lean over cab rails in order to see loads or workers below them. Other crane cabs had been modified by cutting windows in the floor or walls of the cab (covered by glass or open grates) to provide their operators vision of loads below the cab. Cab crane operators indicated that their blind spot, below the cab, was one location where they relied upon information from their hitchers to warn them of hidden obstructions or workers.

One crane with a fixed operating station was observed in the course of our study (a furnace charge crane in one of the foundry operations visited). This crane's operator indicated that his elevated station permitted him a generally clear view of his crane's range of movement. The crane's large magnetic charge bucket moving through this area provided his major visual obstruction. The use of judiciously placed convex mirrors filled his blind spots, and a loud speaker system he controlled was used to alert inattentive floor traffic of the crane's approach.

The location of a crane operator's control station can have an effect on the operator's ability to control the crane's load. Operators of cab operated bridge cranes indicated that much of their control of the trolley and bridge braking functions is regulated by the feel of the braking action they receive through the crane's structure. In contrast, floor crane operators often indicated that smooth movement and braking, and load movement was difficult to accomplish using their pendant's push-button controls. Some of the difficulty pendant crane operators experienced was attributed to their difficulties in precisely regulating their load's movement, and in maintaining proper amounts of pressure on their pressure-regulated control buttons to achieve the desired crane movement. Another problem noted by floor crane operators is a lack of feel for the way the crane is moving from the remote location of their controls. Pendant crane and hoist operators indicated that in order to get sufficient feedback from the crane or hoist's movement, they hold onto the load or part of the attachment system of a moving load in order to better sense the movement of the crane. This often necessitates that these floor operators stand closer to some raised loads than they feel is safe.

The necessity of immediate (non-delayed) feedback for the precise performance of machine tracking tasks has been demonstrated in laboratory situations on a number of different occasions (Bauman 1975, Smith and Henry 1968). The superior performance of tactual feedback as opposed to visual feedback in regards to the accuracy and compliance in continuous tracking tasks has also been experimentally demonstrated (Rothe 1975, Smith and Henry 1968). The cab crane operator receives his feedback of the crane and load movement through the tactual sensations he receives via the crane's structural components, to some degree from the crane's control function levers, and from his visual perspective of the load. The floor crane operator must primarily rely on visual feedback of the load's movement, or tactual feedback from touching the load (delayed due to some damping effect of the hoist cables) to sense the crane's movements which he must control. If the research cited above and the comments of the majority of crane operators on this issue are valid, crane operators located in cabs with lever controls appear to be in a better position to perform precise load movements than their counterparts operating cranes from floor controls.

The determination of the design of a crane and the location of its operator is made by industrial engineering and operations-finance management personnel in the plants we visited. It appeared on occasion that these determinations are often dictated more by economics than operations safety concerns.

No OSHA Standards currently exist which in any way specify the type or operational design of a crane or hoist to be used in specific industrial applications, save the requirements regarding the lifting capacity of cranes. Our studies indicate that the operators of various types of crane or hoist machines feel that the location of their control station, and the design and nature of their crane or hoist controls can have a significant effect on their ability to perform their materials handling tasks and the safe completion of these tasks. What is alarming is that the industrial engineering personnel, with whom we talked, who are responsible for decisions on crane applications, appeared to be oblivious to many of the operations design factors discussed in the preceding pages. Where they were aware of these factors, they were constrained in their decisions regarding equipment selection or conversion (ie., modification of a cab operated crane to a floor operated crane) by short-term economic or personnel utilization considerations, and not by considerations for operations or worker safety (a long-term economic and personnel utilization consideration!).

Considerable differences of opinion regarding the inherent safety of various operational designs of crane and hoist systems exist between crane operators and industrial engineering management. This topic appears to be a necessary area for further investigation and research. This is especially timely as not only was the operational design of the operator-control system found to be crucial to continuous safe overhead lifting, but in an attempt to reduce labor overhead, many of the plants we visited were converting cab-operated cranes to floor operation. While many of these conversions may not compromise operating safety, it was the opinion of interviewed workers that serious safety compromises were involved in many of these changes. Perhaps some standards guidance regarding the design of the operational and control systems of cranes for various industrial application tasks should be developed. While such an OSHA Standard would be unique, design standards related to the design of industrial machines for various use and environmental applications do exist (1910.178(b) Designations and (c) Designated Locations).

<u>The relationship between crane or hoist operation and the attachment and hitching of loads</u> is a key element in the control of overhead lifting hazards. The failure of some aspect of this relationship frequently appeared as a causal element in the crane and hoist accidents analyzed. It was also indicated as being crucial to hazard realization and control by numerous workers. A number of facets of this relationship (the need for communications between hitchers and crane operators and the operator's responsibilities in regard to this communication) have been discussed previously in terms of safety factors which the crane or hoist operator has control of in overhead lifting. A number of elements related to the relationship of load hitching and crane operation are primarily regulated by the hitcher or some component of his work situation and will be discussed later in this section. There are significant aspects of crane operation and load attachment safety beyond the immediate control of either the crane operator or load hitcher which remain. The following discussion will outline some of these situations.

During the preparation of a load for overhead lifting, the crane operators and hitching personnel we talked with indicated that the operator had a number of responsibilities to carry out. These include checking the load path for obstructions, keeping in visual or voice communication with his hitchers or signal persons, making a final determination of the capacity and sufficiency of a load's attachment system prior to lifting the load, and checking the positioning of the hoist above the load to insure the load does not swing when lifted. Whether or not the operator attempts to perform these tasks depends on the competence and concentration of the operator. Since all of these tasks require that the operator be able to see the load and his hitchers and/or hear some signal, factors beyond the operator's control may restrict his ability to perform those tasks for which he is responsible. Crane operators and hitchers noted a number of conditions where operator vision is adversely affected by excessive dust, bright light resulting from the incandescence of molten metal, and physical obstructions (pillars, large objects on the work floor, parts of the crane cab, etc.). High levels of background noise often make voice communications difficult.

Another source of hazard related to the operators of cranes and hoists in the attachment and handling of loads has to do with the coordination required between the crane (hoist) operator and any hitching personnel, or other workers who become directly or peripherally involved in their load handling tasks. The work coordination between many crane operators and hitchers, especially those who have worked together for a long time, is so refined that little more than a slight nod of the head is necessary for communicating lift and hitch signals. Workers indicated that their work patterns become so familiar to each other that overt communications become unnecessary. These same workers indicated that when a new worker came into a load lifting team, extra precautions have to be taken to avoid improperly anticipating the new workers actions and possibly causing an accident. New in this sense includes both newly hired workers and workers who for some reason are transferring into a new job situation. These latter workers, while often having skilled work patterns, may work quite differently from another experienced worker who has been doing the same job.

One of the most serious breakdowns in hitcher-operator coordination was found in a large foundry operation where a number of relatively high bridge cranes are used for setting up and pouring molds. These cab-operated cranes are high, and excessive dust in the air obscures the crane operator's view of the hitcher and load. Because of this, rigid depth perception standards are imposed on the operators of these cranes. This has resulted in the reassignment of a number of older crane operators to less demanding machines. It also broke up teams of crane operators and hitchers who have worked together for many years. These men not only worked well with each other but are also friends and neighbors away from work. The replacements for these older crane operators are much younger men.

The above situation has generated considerable animosity among the experienced hitchers regarding the new crane operators, according to the plant's safety director. This has resulted in a tendency on the part of the hitchers to become hypercritical of the new operator's mistakes, doing little to try to improve their working relationship. The new operators feel somewhat handicapped by their poor visibility conditions, and the communications block between themselves and their hitchers. The safety director acknowledged this problem and indicated that a solution is difficult. He is primarily relying on the foundry supervisors to encourage some communications between the hitchers and their new crane operators.

Since the coordination between crane operators and hitchers is central to much overhead lifting, it represents a social tracking and communications relationship which is crucial to the safety of much crane and hoist use. One of the suggestions of the human factors consultants on this research project is that this crucial relationship between crane or hoist operator, hitcher and/or signal persons should be reinforced by joint training sessions and management-encouraged job-related bull sessions. The point of this extra training and supplemental communication is to enhance the understanding and appreciation workers in overhead lifting tasks have for each other's responsibilities and limitations in performing their jobs. No plant visited had formalized any such program of joint operator-hitcher training or communications. Most of the plants visited who made extensive use of overhead cranes usually employed their crane operators as hitchers prior to their becoming crane operators. None of the OSHA Standards provisions covering overhead or mobile cranes address any aspect of the communication or cooperation which must exist between crane or hoist operators and those involved in their overhead lifting tasks (hitchers, signal personnel, etc.).

The physical nature of the load items and their attachment systems can also affect the way in which a crane or hoist operator performs his machine operation tasks, and the amount of control the operator can exercise in performing these tasks. Previously mentioned are the problems that large, visually obstructive loads can cause crane or hoist operators - especially floor-located operators. Crane and hoist operators are also responsible for checking the sufficiency and proper alignment of the load's attachment system (capacity of hardware for load weight; lack of twists or kinks in chains, ropes or straps; properly set hooks; etc.) before they lift the load. The nature of the load and its attachment system will define the number and type of pre-lift checks and lifting procedures which the operator is expected to perform. Floor crane and hoist operators who perform their own load hitching as well as operating their machines must contend with the responsibilities and hazards of both machine operation and load hitching. These hazard and control factors which are related to the nature of loads and their attachment to cranes and hoists will be discussed in subsequent sections of this chapter.

<u>The physical layout of the workplace and the pace of work output expected from crane or hoist operators</u> are two other factors determined by management and supervisory decisions. Crane and hoist operators indicated this has an impact on crane and hoist operation's safety. As we've noted, such factors as the location of large pieces of equipment or piles of material, traffic aisles and the location of cranes or hoists and these machines' operating stations can all have an effect on the ability of the operator to clearly see his load or projected load path. Factors such as noise and dust which interfere with the ability of a

crane operator to communicate with his hitcher and to clearly see his load and load path are also affected by the layout of the workplace and different machines and processes relative to the location of cranes or hoists. The design of a construction project and the accessibility to the site or lack of it from various angles will, in large part, determine the types of mobile or tower cranes which will be needed for a project, and how these cranes will be used.

As a result of the numerous checks and performance tasks which a crane or hoist operator is called on to perform, crane operators and many of the management and supervisory personnel with whom we talked felt that crane and hoist operations should not be rushed. It was the opinion of many of these industrial personnel that crane operations could not be sped up too much without creating safety compromises which can possibly lead to injury. In spite of this, a number of pressures on crane operators to work at a rate faster than what they felt was safe, were pointed out to us during our study.

While no crane operators interviewed worked on individual incentive pay systems in machine shop operations, the workers who are served by crane operators are often on incentive pay plans. This situation led to one crane operator complaining that she was under constant pressure from these workers to move their loads (for machine set-up) faster than she felt safe. While this situation did produce some tension, she indicated that she was able to ignore the bulk of these demands and work at a rate at which she felt comfortable and safe. Most of the crane operators interviewed indicated that they were encouraged not to exceed what they felt was a safe workrate by their supervisors. Pressures for them to work faster occasionally developed during production rush periods, when extra personnel were put on to help them out.

Many of the hoist operators we interviewed were on some sort of a piece work incentive system (machinists and foundry molding and pouring operations). Some of these workers indicated that this encouraged them to cut corners in order to increase production, often creating some safety hazard. Often a rushed work pace on a foundry molding assembly line resulted in pile ups of materials around hoisting stations limiting hoist operators range of movement to avoid injury should a load slip. On one molding line, workers disconnected a pouring ladle hoist from its' motorized trolley. This allows them to more quickly pour molds by manually pushing the ladle. This introduces a source of overexertion injury and possible burns if the ladle is moved in a jerky fashion.

It was indicated by a number of field consultants for the mobile crane manufacturer we visited that construction site foremen will often pressure crane operators to hurry a job in order to minimize the cost of having a crane at a construction site. They felt this was especially the case where cranes were rented. These men and other construction workers have indicated that cranes are often used when wind conditions are too severe for safe load handling in order to meet deadlines. Other misuses of mobile cranes such as not relocating a crane when lifting a distant radius load weighing near the safe lifting capacity of the crane is called for, or where some avoidable visual barrier exists, are found to be related to some crane use accidents.

The OSHA Standards for Overhead and Mobile Crane Use include operational requirements for the handling of loads (1910.179(n), 1910.180(h)). The procedures and responsibilities of operators in load handling noted in the previous discussions provide the mechanisms to achieve these basic safe operating requirements. When some element of workplace design or work pace acts to inhibit the crane or hoist operator's ability to comply with these basic overhead lifting safety requirements, the safety of the operation is compromised and the spirit of these standards is violated.

The detrimental effects which environmental conditions can impose on the health and safety of all workers and specifically on the ability of crane or hoist operators to operate their machines and safely handle loads, is the final area of operations related hazards to be discussed. In the Encyclopedia of Occupational Health and Safety under the topic of cranes, lifting machinery and tackle; it is noted that many crane operator's work in environments containing "...excessive amounts of fumes, smoke vapors and toxic gases (which) often rise to the height of the crane cab and constitute a health hazard for the operator" (Quinn, 1971, p. 347). The health problem represented by "chronic" exposures to chemicals, dusts and fumes rise and concentrate above the workplace floor, is a serious concern for the well-being of overhead cab crane operators. The detrimental effects which low levels of chemical, physical and psychological stressors may have on the alertness or psycho-motor capabilities of crane and hoist operators pose a hazard to the safe operation of cranes and hoists.

The melt room of one of the foundry operations we visited was attempting, under OSHA compliance orders, to bring lead fume levels into permissible limits. While ventilation on the iron melt furnaces had reduced the airborne lead levels, workers on the melt platform were required to wear respirators. However, because voice communications between workers necessitated the frequent removal of respirators and other failings of these personal protective devices, the blood lead levels of many of the melt platform workers increased to levels which required their rotation out of the melt room area. According to union officials we talked with, the transfer crane operators, whose cab is located above the melt furnaces, were "dropping like flies" from lead intoxication.

A discussion with one of the transfer crane operators indicated that he knew of a number of other transfer crane operators whose blood lead had risen to levels which required their rotation out of the melt room. He also indicated that he and other transfer crane operators often complained of feeling extremely fatigued by the end of their shifts. They felt that this fatigue was a result of their exposure to the furnace fumes.

A NIOSH study of the behavioral effects of lead exposure (Repko, et al 1975) indicates that psychomotor coordination, sensory and psychological functions, and task performance were all adversely affected by increasing blood lead levels. Since these impaired functions include those which crane operators rely on to perform and regulate their job tasks (hearing, visual-motor coordination, tactile-motor coordination), the lead exposures these crane operators receive not only affects their own health, but also their ability to safely perform their job. This, in turn, affects the safety of all those working around the transfer crane.

Other behavioral toxicology research has shown significant behavioral and physiological function impairment for low level exposures to various chemical substances likely to appear in the environments of crane and hoist operators. A NIOSH study of the effects of carbon monoxide on vigilance performance showed that eye-hand coordination in tracking tasks, response times to visual targets, auditory monitoring accuracy, and neurological functions were all adversely affected by carbon monoxide exposures producing a 5% carboxyhemoglobin (blood level absorption) level (Putz, et al 1975). Carbon monoxide is a likely air contaminant in any industry where combustion is part of an industrial process or where diesel engines are used. The noted behavioral effects of carbon monoxide may present hazards to safe crane or hoist operations in some foundry operations as well as mobile crane uses. Other negative behavioral effects of various industrial substances are documented in the published proceedings of a NIOSH seminar on behavioral toxicology (Xintaras, et al 1974).

Chemical substances are not the only stressors which may have negative effects on crane or hoist operator's health and possibly on overhead lifting safety. Physical and psychological stressors experienced by crane and hoist operators may also generate crane use safety hazards. For example, exposure to high noise levels is discussed in an ergonomic study of mobile cranes (White, 1973). This study found 59% of the mobile cranes studied had crane cab noise levels which averaged in excess of 90dBA. Five cases of hearing loss due to occupational noise exposures are reflected on the Wisconsin Workers' Compensation Case History File (from 1972 through October 1977) for workers whose occupation is listed as crane or hoist operator. The industries from which these workers come (foundry; metal stamping, forging and fabrication) indicates that they were probably in-plant crane operators. Whether prolonged exposure to high noise levels has a detrimental effect on a crane operator's abilities to perform his job tasks (beyond complicating communications) is not immediately clear.

Psychological stresses have been shown to relate to a number of illnesses, notably hypertension and cardiac problems. The general finding is that increased stress is positively correlated with poorer physical or mental health (Margolis, et al 1974). Crane operators are in an occupation with a high stress potential. Factors of job responsibility, complexity, routine and production time demands may combine in a destructive as well as a beneficial manner. The demands (stresses) of safely operating a crane, attaching loads properly for lifting, maintaining effective communications, etc., can adversely affect the workers' health or behavioral abilities. For example: the authors of the study of construction equipment operator's mortality data (Decoufle, et al 1977) hypothesized that increased involvement in non-working traffic accidents, among heavy equipment operators may be the product of a stress reaction, inattention or laxity while driving in traffic, as a reaction to the high concentration and attentional demands on these operators from their job tasks.

Overexertion injuries (mainly back and trunk sprains, strains, dislocations and hernias) account for 32% of the Wisconsin Workers' Compensation cases reported for workers whose occupation is indicated as a crane or hoist operator (1972 through October 1977). Many of these overexertions are probably the result of accumulated physical stresses. It is also possible that the bouncing around some crane operators receive from their machine's movements; or strains introduced by poor seat cushioning and lower back support, and lack of adjustment for comfort or accessibility to controls, are chronic exposure factors contributing to the development of these injuries. The mobile crane ergonomics study (White, 1973) reported that a number of crane operators complained of back problems they felt were due to poor seat design. Our study uncovered a few complaints of pains attributed to the jerking of both mobile and overhead cab operated cranes or to poor seat design, however, this type of problem was complained of much more often by forklift truck drivers. Whether the pain caused by these conditions or injuries affects the concentration and alertness of crane or hoist operators is a topic requiring further study to evaluate.

Construction equipment operators (including mobile crane operators) experience significantly higher than expected death rates from cancer (especially respiratory system cancers), respiratory system disease, digestive system disease, and violant deaths (especially accidental death) according to the results of a study of 2,190 deceased construction equipment operators (Decoufle, et al 1977). These authors hypothesized that the respiratory problems could be related to dust and sand at construction sites. The increased frequency of lung cancer deaths is indicated as primarily associated with crane men, derrick men, hoist men and shovel men in other mortality studies cited in this study.

The control of environmental stressors must rest to a large degree on management and governmental activity. The current OSHA Standards which cover the control of substances which may create occupational health problems are currently being expanded and strengthened. These standards primarily emphasize the maintenance of threshold limit values for various substances and monitoring of worker's health when some substances exist in the workplace. An alternative or supplemental emphasis on the development of workplace practices for the proper handling and control of dangerous industrial substances and proper hygienic behaviors has been proposed by Dr. Jean Stellman (1977). A continuing effort to control toxic exposures and their attendant occupational diseases seems necessary.

The behavioral effects of chemical, physical and psychological stresses is less clearly understood than is the problem of chemical exposures and occupational diseases. Understanding of the long term health effects of many stressors (noise, vibration, time stresses, etc.) are just beginning to be evaluated. The immediate (acute) effects these environmental stressors might have on safe industrial operation (such as the use of cranes and hoists) has, for the most part, not been defined. Current knowledge of the effects of some of the stressors described above indicate they may play a significant role in industrial accidents. For this reason further study of these areas is called for.

B. BEHAVIORAL FACTORS IN LOAD ATTACHMENT AND LOAD HANDLING SUPPORT IN OVERHEAD MATERIALS HANDLING

Load hitchers, signal personnel and load handlers involved in the use of cranes and hoists to move materials in industry, because they must be in close proximity to lifted loads, are the most frequent victims of the types of accidents described in Tables 5-1 and 5-2 and elsewhere in Part III of this chapter. These workers are also integrally involved in the attachment of load items to cranes and hoists for lifting. Since a majority of crane and hoist accidents result when attachment systems fail or loads slip from their attachments and fall, it would be anticipated that these workers can play a significant role in the control of load attachment hazards. The results of our study indicate that this is indeed the case.

Personnel involved in the attachment and handling of loads to be moved by cranes and hoists have five basic tasks and/or responsibilities which our study uncovered.

1. The at-site selection and inspection of the attachment hardware to attach a specific load item to a crane or hoist.
2. The application of this attachment hardware in the actual hitching of the load to the crane or hoist.

3. Assisting the crane operator in checking the load hitch and attachment hardware for sufficient condition, adequate capacity, and secure attachment before the load is raised to travel height.
4. Maintaining voice or signal communication with the crane operator to alert him to any problems with the load's attachment system, provide information on visual blind spots, help guide the load to its destination, give lift signals, etc.
5. Insure that they (the hitchers or signal people) do not get injured in the process of lifting and moving loads.

The degree of responsibility an individual hitcher or signal person has in a lift is determined by the nature of the load item and its purpose in being lifted and moved, the hitcher's other responsibilities in regard to the load item, and the layout of the workplace relative to the location of the crane operator. When a floor operated crane or hoist operator also handles his own hitching he must perform both the operator's and hitcher's tasks, as well as being exposed to the same hazards as the hitcher.

Hitchers and signal personnel perform important tasks in the process of overhead lifting of loads. The first four points in the preceding list speak to these tasks. While crane operators usually have the final veto over the use of one attachment device or another, we found that in practice the hitcher usually selected the attachment sling or clamp device from those available to attach a specific load. The crane operator's role in this task is usually only corrective, rejecting a hitch system when he feels it is insufficient for some reason.

Hitchers are also responsible for checking over attachment hardware for damage prior to its use, and tagging defective pieces of lift hardware for repair or replacement. The plants we visited all had some periodic (weekly or monthly) check of their attachment hardware by specially trained personnel. These regular inspection programs are all supplemented by training programs for hitching personnel to instruct them in how to detect and avoid damage to lifting hardware, as well as how to properly attach loads with the hardware they use.

The prior section on crane operations explained many of the functions that hitching and signal personnel provide to crane or hoist operators by supplying them with information on the load's behavior or the load path. As a function of the difference in the position of the hitcher or signal person and the crane operator each worker can see certain aspects of the load better than the other. By communicating problems to the crane or hoist operator that the operator can't see as well as the hitcher's perspective allows, load handling safety is improved. A number of the hitchers interviewed indicated that they first hitched large loads on the load's side visible to the crane operator and then hitched the load on the operators blind side. Then they checked the hitch and stood clear of the load, in clear view of both the operator and the operator's blind side of the load, before giving the signal to lift the load. In this way they are able to alert the crane operator should any problem with the hitch develop on the operator's blind side when the load is lifted.

Since the hitcher, in many circumstances, makes major decisions as to what available attachment hardware to use to hitch a load, and hitching personnel are in the best position to detect damage to attachment hardware; these workers should possess the skills and tools necessary to perform these tasks. This requires that the hitcher have at his disposal the proper types and kinds of attachment hardware (clamps, chain slings, nylon straps, wire rope slings, hooks, etc.), and know how to properly apply and inspect these devices when used for attaching loads.

During our discussions with hitching personnel we were told that occasionally they have to substitute less appropriate slings or clamps for the proper slings because the proper slings have disappeared from their nearby storage locations. These workers indicated that the demands on their time didn't permit them to search for slings which have "wandered off". This points up the need for plant management and supervision to establish a system for keeping appropriate attachment devices available at the sites where they will be used. This means that when a sling or clamp is removed from service due to damage or wear it should be promptly replaced with a suitable substitute, to eliminate the need for workers to borrow slings from surrounding stations. The lack of proper slings, etc. or their regular "disappearance" was indicated as the reason for some workers locking up needed slings or hooks, in order to insure their continued availability. In plants with multiple shifts or where a variety of hitchers use the same attachment hardware, load attachment device managers indicated this type of hoarding led to expensive duplication of attachment materials.

OSHA Standard 1910.184 - Slings, provides detailed information on considerations of capacity, configuration, inspection, repair and application for slings and their attachments constructed from a variety of materials (alloy chain, wire rope, and metal or synthetic mesh). The provisions of this standard do not require workers who select and apply slings in industrial overhead lifting be familiar and knowledgeable with the provisions of the standard. However, the provisions of this standard pertaining to safe operating practices (Part (c)) and inspections (part (d)) imply that those workers selecting and applying slings be familiar with the provisions of these and appropriate subsequent sections of the standard.

The industrial establishments we visited varied in the manner and extent to which they trained their hitching personnel. At a minimum, hitching personnel (and crane operators) have been supplied with pocket charts showing lifting capacity for various sizes and configurations of slings of various materials. One of the best of these guides is a four-page pocket folder published by the Harnischfeger Corporation, including paraphrased listing of OSHA Standards requirements (safety do's and don'ts), as well as capacity charts for alloy steel chain and wire rope slings. The more sophisticated hitcher training programs include annual hitcher training sessions with trained plant personnel or sales and training representatives from hitching hardware suppliers or manufacturers. While the extent to which various hitchers felt the training they received aided them in their daily job tasks varied, most hitchers felt the training and instructional materials they received alerted them to possible problems they might experience. Workers who had to deal with a wide variety of loads and hitching hardware generally found their training of more value than did hitchers performing more routine tasks.

As mentioned at the beginning of this discussion, hitchers, signal personnel, and floor located operators of cranes and hoists are exposed to injury hazards due to their close proximity to loads to be lifted. Our study of accident data and worker's opinions indicated that these hazards come from three major sources: 1) Being struck by a falling load or load part when the load is lifted or moved; 2) being struck or pinned by a load which swings when lifted or moved; and 3) getting fingers or hands caught in hitching hardware between loads and hitch hardware when the hitch is being tightened or the load lifted. Both hitchers and crane operators had opinions on these hazards and how injuries can be avoided. These are presented in Tables 5-6 and 5-10 and are summarized below.

The principal protection against injury from lifted loads unexpectedly swinging or falling was indicated to be avoidance of being within the possible swing or fall radius of a load when it is lifted. A number of factors limit the ability of these workers to avoid possible falling or swinging loads. These include the need for hitchers to hold hooks while a hitch is being tightened, and objects or materials around a load to be lifted blocking a hitcher's escape routes should the load swing or fall.

The prevention of loads swinging or falling to injure a hitcher or other worker focuses on the use of proper safety procedures in the attaching and lifting of loads. These consist of: sufficient communications between the hitcher and operator when attaching and lifting the load; the operator making sure the hoist is centered above the center of gravity of the load and hitch; and initially lifting a load only a few inches to make sure it is securely hitched before the load is lifted to its travel height. To prevent caught-in accidents involving hitching apparatus, crane operators indicated that they tried to avoid lifting or tightening loads when their hitchers' hands were vulnerable to getting caught, they generally indicated that hitchers have to be careful to avoid possible caught-in situations. Hitchers indicated the need to be careful how they hold chains and hooks while setting slings, to make sure they have their lift signals with operators straight, and to avoid turning their backs on crane operators blocking their view of the hitcher's hands. The chance of a wire rope sling twisting when the load tension is relieved was pointed out as another possible source of a caught-in injury.

C. PHYSICAL CONSIDERATIONS FOR SAFETY IN LOAD ATTACHMENT SYSTEMS

The previous section indicates that the proper attachment of load items to cranes and hoists is a significant component of safety in overhead lifting. The prior discussion emphasizes the role that hitching personnel perform in this aspect of overhead materials handling. The other side of the load attachment picture is the physical design and function of the attachment systems which provide the essential bond between the load and the load hook of the hoist or crane.

We found a wide variety of devices used to provide the bond between load and lifting machine. These include slings of a wide variety of design and component material, various standardized and custom clamps and grabs, magnets, vacuum units, etc. Besides the need for skilled workers to select and apply these attachment systems properly, our research indicated these attachment systems need to meet a number of other criteria to insure safety in their use.

Any load attachment device basically has to be of sufficient capacity to lift the weight of the loads they are required to attach. Their reserve capacity has to be sufficient to handle the weight of the load and the inertial effects of the load created by the (possibly jerky) movement of the crane or hoist. To prevent an accident occurring from a failure of some component of an attachment device, it not only has to be of sufficient load handling capacity when it is new, but also after it has suffered the routine use and abuse to which this industrial apparatus is exposed. Damage which reduces the capacity of attachment hardware from improper use, attachment, or storage and wear beyond tolerable limits must be avoided and detected before some failure in the attachment systems occurs.

In addition, a load attachment device has to be designed to be able to hold onto its intended load, to keep it from falling despite a certain amount of jerky movement which may occur when loads are moved by crane or hoist. This is not always achievable with all combinations of load and attachment device. A number of foundry operations we observed used magnet attachments to lift scrap iron and steel to charge their melt furnaces. Operators of these charge cranes noted that some scrap pieces which are attracted strongly enough by the magnet when the magnet is raised can fall with the slightest jerk of the crane's drive mechanisms.

For this reason all traffic below the charge crane's magnet is tightly controlled and no lifting is done when personnel are in these areas. Because grab type clamp devices, vacuum attachment systems and other systems which attach their loads by attraction (rather than cradling loads as a sling or hook does) could lose their attraction because of power system failure or reduced grab capacity from wear, traffic below loads handled by these attachment systems is usually avoided, according to our observations.

The majority of attachment systems in the factories visited are slings, primarily of alloy chain, but also constructed of nylon web, metal mesh and wire rope. A variety of specialized attachment devices were also observed. These ranged from simple gravity plate clamps to specialized and customized hydraulic and vacuum devices. These are designed to handle load items which would be difficult if not impossible to attach by slings. While these special attachment systems improve the ease and security with which many load items can be attached to hoists or cranes, their special design and mechanical systems may require special inspection and adjustment. Rigid special attachment devices, such as clamps, should be attached to crane or hoist hooks by a flexible chain or by safety latch hooks. A fatal accident occurred when a rigid plate clamp slipped out of a hoist hook when the plate was placed up on a work table, allowing the metal plate to fall on the hoist operator.

Slings constructed from alloy steel chains provide their users with a tremendous amount of flexibility in tailoring their sling design and their ability to rapidly make repairs to damaged slings or build customized attachment apparatus. By maintaining a supply of chain, hooks, attaching rings and coupling links, even small industrial establishments can build their own custom designed slings by cutting chain to desired lengths and attaching appropriate hooks, clamps, etc. This in-house sling availability allows for much faster turnaround time in the replacement of damaged sling components, making it more likely that workers will report sling damage and remove potentially dangerous slings from use.

Chains of alloy steel, although extremely strong, are susceptible to link damage from a variety of sources (crushing, welding arc, cutting, high temperature exposure, metal fatigue stresses, twisting, etc.). Since a chain is only as strong as its weakest link, employees using chain slings should know how to avoid and detect damage to chain links. The susceptibility of chains to sudden failure and a number of other problems enumerated by Dickie (1976) make chains undesirable for use in construction. Slings constructed from wire rope components, which fail strand by strand rather than suddenly, and are less prone to damage by crushing than chains, are commonly used in construction applications. Wire ropes can experience internal damage. This is not always readily detected by an untrained inspection of the rope's surface. Wire rope also can be damaged by kinking, sharp bending and abrasion. Another common sling material, nylon mesh, while being extremely strong and slip resistant, requires special machines to construct them and usually must be custom made. Nylon straps will stretch before they break, unless they get cut. These synthetic mesh slings can be easily cut by sharp edges on the loads they handle; for this reason they should be padded at sharp edges to avoid damage.

Both slings and special attachment systems need to be applied properly and inspected regularly to insure their continued safe use. The provisions of the OSHA Standards on Slings (1910.184) provide detailed requirements on the use and inspection requirements for slings and hooks of various materials. There are no such standards covering the use and inspection of specialized attachment systems used in overhead lifting. Our study indicated that certain specific operational systems of specialized attachment devices need inspection attention to insure that they continue to function safely. These operational components of special attachment devices which require special attention are: biting edges of clamps; attachment rings for these devices (which often wear in visually obscured areas); and power systems and lines for magnets, vacuum units and hydraulic devices.

Most of the preceding discussion has focused on considerations of the attachment systems being of a proper design to meet the demands for attaching and lifting the loads they attach. The other facet of load attachment is the suitability of the load item itself to be attached and handled. One of the most organized programs of materials lifting planning was found in a large custom-designed equipment manufacturing plant where large sub-assemblies had to be manipulated by cranes for construction and assembly. In this operation a major part of the engineering effort to design the machines produced and to to plan their construction is the anticipation and preparation for the attachment of various unusual shaped and sized loads. This load lift planning, translates into providing marked centers of gravity and load weight on the plans which accompany odd shaped or weighted pieces. Where design, lifting, and industrial engineers; and consulted crane operators and hitchers feel they are necessary and structurally feasible, lifting shackles, holes to set hooks and other welded attachments are added to large sub-assemblies to facilitate their attachment to cranes for handling and manipulation.

D. PHYSICAL CONSIDERATIONS FOR SAFETY IN THE MACHINES USED TO PERFORM OVERHEAD LIFTING TASKS

The emphasis, earlier in this section, on the importance of the crane or hoist operator in regulating safety in overhead lifting is not meant to disregard the important safety component provided by the machines which perform the tasks of lifting and transporting loads. Our study failed to find any physical design elements of any crane or hoist system which represents an inherently unsafe operational component of these machines (with the possible exception of brake systems). What our study found as the cause of hazards to overhead lifting safety from the physical character of the lifting machinery was the failure of the machinery to operate in an anticipated or desired manner. This type of failure is most likely to develop when the functional mechanisms of the crane or hoist aren't maintained in proper working order, or when a crane or hoist is used to perform a load handling task which approaches the limits of its control systems sensitivity or load handling capacity.

As an example of this latter point, the manufacturer of wire rope industrial hoists we interviewed produces two types of hoist lift and lower push-button controls - a single speed control and a five-speed stepped control system modulated by pressure on the control button. The single speed control tends to start and stop abruptly because it has to achieve a compromise between smooth starting speeds and acceptably rapid raise-lower speed. Where precise load movement is not a consideration, this sort of hoist, assuming adequate capacity, will perform sufficiently. Where precise movement or alignment of loads with machinery or for assembly is required, single speed controls were found lacking by a few of the hoist operators we interviewed. Since the movements of a single speed regulated hoist are abrupt and jerky, hoist operators often must repeatedly punch, lift and lower buttons to achieve proper load alignment. The multi-stepped controls allow the hoist operator to inch (or millimeter) his loads into position.

This control's sensitivity design factor proved to be more than just a minor annoyance in using hoist equipment. The more frequent button pushing (often required of single step control hoists) seemed to generate more hoist operator maintenance complaints of sticking or worn control cellenoids. Constant and repeated charges in directional torque that single speed controls impart on the mechanical compoents of hoists, according to their manufacturer, lead to more rapid deterioration and failure of hoist drive components. These physical problems can cause a hoist to wear out early or fail to function unexpectedly, leading to the sort of hoist accidents whose hazards are summarized in Table 5-9. The hoist manufacturer indicated, however, that because of the extra cost of the multi-step controlled hoist, short term economic considerations lead many customers to purchase the single speed hoists for job applications more suited to the performance aspects of the multi-speed hoists. In the long run, many of these customers ended up having to overhaul or replace their hoists much sooner than anticipated because of this mis-match of equipment with job task.

The same sort of machine capability mis-match with the equipment's use was found to relate to the lifting capacity of cranes and hoists relative to the weight of loads they are consistently called upon to handle. This problem breaks down to the simple fact that a 60-ton crane which seldom lifts loads in excess of 50 tons will develop maintenance problems with less frequency than a 50-ton crane constantly lifting loads near its' capacity. The former equipment application will result in a crane which will have less down time or will operate reliably and smoothly longer than the latter application, given equivalent preventive maintenance and equipment inspection efforts. In the long run, the equipment reliability and safe operations assets of the heavier capacity crane and the flexibility its existence provides production planners will offset the increased acquisition cost this crane represents over the smaller crane.

The disadvantages of the 50-ton crane above can be offset by increased attention to inspecting, detecting and quickly repairing the accelerated wear it will experience if constantly used at or near its limits. This is no minor commitment, however, as we found one plant with 55 bridge cranes, most of which are frequently called on to perform near capacity lifts, employ the equivalent of seven full-time crane maintenance experts and apprentices whose only job is to keep cranes and hoists functioning properly.

Another factor of crane and, to a lesser degree, hoist design which has an effect on the speed of overhead materials handling is the gearing on the drive systems of hoisting, bridge and trolley travel systems. For an equivalent lifting capacity machines the cost of a more rapid travel system may be a substantial increase over a slower crane. However, if the demand for the crane's services is substantial, a quicker crane may make the addition of a second crane unnecessary and may provide the crane operator with some break time between lifts. One less expensive measure bridge crane owners may take to speed the functions of their machines is to select a secondary or auxiliary hoist of appropriate capacity to supplement the main hoist of the crane. Since smaller supplementary hoists operate at up to two to three times the rate of main hoists, they are more efficient for lifting lighter loads. If a 40-ton main hoist is supplemented by a 5-ton auxiliary hoist, only large enough to perform 30% of the crane's lifts, converting to a 10-ton auxiliary hoist able to handle 80% of the crane's lifts may result in a significant increase in machine efficiency.

The lack of a motorized trolley system on some hoist systems (chain hoists, jib-pillar cranes, materials hoists, etc.) requires the hoist's operator or assistant to move hoists and loads along their rails by manual gear drives or by manually pushing or pulling the hoist or load. While manual gear drives for trolley and hoist functions, often found on chain hoists, occasionally are related to overexertion injuries involving their operators, pushing or pulling on hoist or load are factors which were indicated in a number of accidents. These push and pull related injuries were overexertions from pushing hoists on rough running trolley rollers or from trolleys hanging up on rough spots on hoist rails (welds), load items falling when pushed out of their hitch, and injuries occurring when handles used to pull or crank hoists loosen or fall. These are problems most likely related to poor maintenance in relation to hoist design.

Another functional component of hoists as well as cranes which received a disproportionate amount of operator criticism is brakes. These complaints revolved around brakes' lack of sensitivity, hypersensitivity, lack of holding power and often just plain lack of brakes. This study did not find any specific make or type of brake which consistently causes problems; although some types of crane or hoist brakes may possess chronic problems, further study would be necessary to point these out. As previously noted, operators of bridge cranes working from attached cabs felt they had better control of crane and hoist braking due to the feel of the braking action of the crane they received through the crane structure. Some of these bridge crane operators did complain of too much or too little sensitivity in some of their crane's brake mechanisms. Floor crane operators complained of difficulty in being able to modulate their crane's brakes from the push button controls which activate various crane brakes. Hoist operators who have brakes, on occasion had the same complaints as floor crane operators. Some operators indicated they have difficulty controlling trolley movement on hoists which use opposite directional controls to perform braking functions. Many hoist operators complained of inadequate holding brakes on their hoists, especially when lifting near capacity loads.

Many of the problems mentioned above and others involving the physical functioning of cranes and hoists can be detected and corrected by adequate inspection and maintenance of cranes and hoists. The OSHA Standards covering Cranes (1910.179 and 1910.180) specify a number of component systems which must be inspected at vaguely specified intervals. These intervals, frequent and periodic, are left unspecified but should be of appropriate duration to reflect the amount of use and the extent of use a crane gets. Most regularly used cranes should have their major control systems checked before being put into use at the beginning of an operator's shift, and should receive more complete inspection of all mechanical systems subject to wear or stress fatigue at appropriate intervals. In most cases, crane purchasers are supplied with documentation on crane and hoist inspection and maintenance from the equipment's manufacturer. The crane and hoist users we visited have translated OSHA and manufacturer inspection and maintenance requirements into check lists specific to each type of machine they use.

The design specifications of the ANSI B 30 standards appropriate for Overhead and Gantry Cranes (B 30.2.0 1967 - revised in 1977) and for Crawler, Locomotive and Truck Cranes (B 30.5 - 1968) are incorporated into OSHA standards 1910.179 and 1910.180 respectively. The other provisions of each of the above OSHA standards seem to be based at least in part on their corresponding ANSI standards. Other pieces of overhead lifting equipment, hydraulic boom cranes, monorail cranes, overhead hoists, chain hoists, etc., covered in their own subsection of the ANSI B 30 standards do not have these standards design specifications incorporated into the mandatory OSHA Standards (ANSI Standards are voluntary). Whether the pieces of overhead lifting equipment whose design is not addressed by OSHA are covered by the subsequent portions of the two OSHA Crane Standards is unclear to most field users of these pieces of equipment. The answer is regrettably that they are not covered; since hoists and hydraulic boom cranes have their own unique hazards to their safe operation, they should have OSHA standards regulating their design, inspection, maintenance, operation and usage. Currently the advertising claim that a hoist "meets all OSHA Safety Standards" is of no real value.

V. CONCLUSIONS AND RECOMMENDATIONS

The use of cranes and hoists in overhead lifting defines a system of factors which interrelate and integrate to accomplish load lifting tasks. As defined in the preceding section the ergonomic factors involved in this system encompass the nature of the design and operational use of cranes and hoists, and the application of the attachment systems to handle these loads. The lynchpin holding down the major responsibility for safety in these systems is the crane or hoist operator. These operators cannot be expected to achieve safe operations without cooperation from their load hitching assistants, and plant management and supervision who determine a variety of crucial elements of overhead lifting operations. These management-determined factors run the gamut from equipment selection to the allocation of manpower resources for maintenance and inspection; to the selection of operating, hitching and signal personnel; to the determination of the training, knowledge and encouragement toward the safe performance of their jobs that overhead lifting personnel receive.

The single most effective effort for safety in overhead lifting would be the determination of the specific hazards to safe crane or hoist use which exist for specific uses of lifting equipment. This, coupled with the development of mechanisms to inform operators and associated workers of the nature of these hazards, and encouraging work practices which will provide controls for these hazards, can have a profound effect on improving overhead lifting safety. This suggestion embodies the concepts of the hazard management scheme and especially the development of safe operations performance standards discussed in detail in Chapter 2.

The effort of detecting and controlling work hazards should have a meaningful contribution from a variety of sources including: shop floor workers, supervisors, managers, equipment manufacturers and suppliers, regulatory and enforcement agencies, and research into various critical aspects of safety in the work process. The purpose of each of these groups' contributions should be to enhance the knowledge and ability of those workers and supervisors involved in overhead lifting regarding the recognition of hazards to safe operations and the prevention of these hazards developing into accidents. The preceding sections of this chapter have tried to define some of the sources of hazards that we found to exist in overhead materials handling, and to point out some of the considerations which might be taken into account in developing mechanisms to control these hazards. The following discussion will try to illuminate some of the directions which might be taken to achieve preventive management of crane and hoist use hazards.

Since the performance of the personnel involved in the operation of cranes and hoists and those involved in attaching loads to lifting machines, and the nature of communications between these two groups of workers, were found so critical to safe overhead materials handling, efforts to optimize the safe performance of the tasks of these workers in load handling should be beneficial. As previously mentioned, these efforts should be directed at increasing the knowledge and skills of these workers to prevent accidents by detecting hazardous conditions in their jobs and controlling these hazardous conditions. There are a number of directions which might be pursued in respect to the above. Mechanisms to assess the opinions of involved workers as to the hazards they find in their job tasks and how they control these hazards, such as the hazard survey technique used in this study (Coleman and Smith, 1976), can provide valuable information from which to develop materials to further develop safe work performance standards and to educate workers in safe operations. The ultimate training of overhead lifting safety to workers should be an on-going process, utilizing the knowledge resources of the workers themselves as well as the accumulated knowledge and experience of the manufacturers and suppliers of lifting hardware.

NIOSH, as a part of its mission to train workers and managers in industrial health and safety, should develop materials to serve as resources for educating overhead lifting workers in safe operations. As a part of this effort, guidance should be given to managers in industry as to how to tailor worker safety training to the needs of their particular situation. Hazard management principles should be of value in this effort.

A large number of factors in overhead lifting safety require resources beyond the limits of any single worker's skills and competence. The current OSHA Crane Standards address many of these factors, such as equipment design, inspection, operation and maintenance, in at least a satisfactory manner. Other of these factors: the skills and knowledge level of workers; the match of equipment functions and operating limitations to load handling requirements; and basic worker protections from the hazards of insufficient design, inspection, maintenance, operation, etc. of lifting equipment not covered by the Crane Standards (hoists, hydraulic boom cranes, etc.) are not now addressed by the OSHA Standards. Efforts to address these areas through appropriate standards, and an expansion of governmental efforts to insure and aid in achieving workplace compliance with current health and safety standards should be undertaken.

In addition to the above areas of standards insufficiency, an additional area of research into overhead lifting operation safety seems appropriate. This area revolves around the question of the effect of incipient levels of environmental stressors (chemical exposure, whole body vibration, psychological stresses) on workers such as crane operators or load hitchers whose job requires periodic intensive concentration. While considerable efforts are being expended in efforts to evaluate the long-term effects of exposure to these stressors, little attention has been given to determining the possible effects that day-in and day-out exposure to combinations of these stressors have on safe and attentive job performance.

In general our study found that safety in crane and hoist use in materials handling is synonymous with proper and efficient operating procedures. For this reason, emphasis on operations safety should be treated as part and parcel of consistently efficient production. While manufacturing processes which compromise safe operations may generate faster production, the costs of possible damage or injury, should these short-cuts produce accidents, if not prohibitive in regards to business economics is intolerable in regards to the societal damage occupational injury and illness represents. In the long run, safe overhead lifting operations are productive operations. A number of the long-term benefits which short-term sacrifices for safety generate, pointed out in Part IV of this chapter, speak to this point.

VI. SUMMARY

The purpose of this study of crane and hoist use in overhead lifting was to utilize accident data to derive causal patterns for accidents involving this equipments' use, and to assess the validity of these patterns through observation of the use of this equipment in industrial practice. As an adjunct to the above effort an attempt was made to evaluate the human factors components involved in the safe use of these machines.

The data analysis and field observation data, presented in Section III of this chapter, confirmed that the bulk of the safety hazards associated with crane and hoist use arise directly from the processes involved in the attachment of loads to cranes or hoists, and the subsequent lifting and transportation of these loads. The most significant source of injury associated with crane and hoist use was found to be lifted loads falling because of some insufficiency in the attachment of the load to the crane or hoist; or loads falling as a result of improper operation of the crane or hoist machine (excessively rough or jerky movement loosening the load from its attachment or some failure of the support mechanisms of the crane or hoist system). Other significant sources of injury arising from the handling of loads by cranes and hoists involved: loads being lifted or moved, or moving crane structures striking workers or objects in their environment to cause some injury; workers becoming entangled in loads and their attachment hardware when loads are lifted or positioned; manual exertions involved in preparing a load for attachment or manipulating a lifted load causing an overexertion injury; and workers involved in moving loads, falling over debris in their workpath. The other significant source of injuries associated with cranes and hoists result from working on or around these machines (maintenance, entering and leaving, etc.).

The evaluation of the human factors considerations in crane and hoist use safety yielded a picture of a system of physical and behavioral components that dynamically interrelate in the processes involved in overhead lifting. This system's components break down into four main areas: the operation of cranes and hoists in overhead lifting processes; the process of attaching load items to cranes and hoists; the design and sufficiency of the devices used to attach loads to cranes and hoists; and the design and functional consistency and sufficiency of the crane and hoist machines themselves.

Of the above factors the role of the crane or hoist operator in the process of overhead materials handling is central to assuring safety in crane and hoist use. The operator, through his task activities, controls a large number of factors critical to overhead lifting safety. The operator, however, must rely on the performance, signals and judgments of the load hitching and signal personnel with whom he works. These hitch and signal personnel were found to play a significant role in a variety of aspects of safe overhead lifting, especially in load attachment. The bond of communication between the operator and load hitcher or signal person was found to be one of the most significant elements contributing to safety in crane and hoist use.

In addition to these primarily behavioral factors relating to the roles played by the operators, hitchers and signal personnel, a number of principally physical factors related to the apparatus used to attach loads to cranes or hoist, and the cranes and hoists themselves were found to represent significant components of safety in overhead lifting. For the load attachment system the design of the system for its use requirements, their availability, inspection and match with the load were major factors concerned with the sufficiency of the attachment of the load to the crane or hoist. The crane or hoist machine must function in a consistently predictable manner, have an appropriately designed and located operating control system, and in general be of sufficient design to perform the tasks required of it in order to allow its' operator to safely move materials with the crane or hoist.

In order to govern the interaction of these physical and behavioral components which determine the safety of overhead lifting, both workers, managers, supervisors, and equipment manufacturers and suppliers must all play important roles in the detection and control of overhead lifting hazards. Each of these groups, because of the distinctive knowledge and control of safety hazards they possess, can provide unique support to a positive program to prevent crane and hoist use hazards from becoming accidents. Workers, due to their immediate relationship to the equipment and job tasks involved in overhead lifting, can perform crucial functions in detecting and communicating hazards to safety from their job tasks and equipment, and can through their job performance control many of these hazards. Managers and supervisors have the responsibility to insure that the use of the physical and personnel resources provided for in overhead lifting are sufficient to assure safe operations. Their task in this respect can be made more realistic if they can optimize the use of the information and skills of their workers and equipment suppliers and manufacturers. This latter group must develop and provide equipment of appropriate function and design to meet the overhead lifting needs of their customers. To meet these needs these businesses not only have to build or sell safe devices and machines, but they must also aid the user in determining which types of equipment best meet their needs, and provide guidance as to the safe use of the equipment.

Regulation of safety in overhead lifting through the OSHA crane and sling standards has had a profound effect on improving the consciousness of those involved in overhead lifting in a number of significant areas of crane and sling design, inspection, maintenance and to some degree operations usage. The OSHA standards appear to need some strengthening in areas involving the utilization and assurance of skills and knowledge sufficiency of the personnel directly involved in overhead lifting, in matching equipment design and function with task requirements, and in providing protective coverage to those affected by the use of hoists, hydraulic boom mobile cranes and other overhead lifting equipment not covered by the current OSHA standards governing cranes and slings. These standards shortcomings and the other human factors areas mentioned above are discussed at greater length in Sections IV and V of this chapter and in Chapter 2.

References

Bauman, R. D. A Cybernetic Analysis of Delayed Feedback in Simulated Automobile Steering, Doctoral Thesis, University of Wisconsin, Madison, 1973.

Cleveland, R.J., H.H. Cohen, M.J. Smith, A. Cohen. Safety Program Practices in Record-Holding Plants, HEW Publication - in press.

Cohen, A., M.J. Smith, and H.H. Cohen,. Safety Program Practices in High Versus Low Accident Rate Companies - An Interim Report (Questionnaire Phase), HEW Publication No. (NIOSH) 75-185, June 1975.

Coleman, P.J., and K.U. Smith. Hazard Management, Preventive Approaches to Industrial Injuries and Illnesses, Wisconsin Department of Industry, Labor and Human Relations, Madison, 1976.

Decoufle, P., J.W. Lloyd, and L.G. Salvin. Causes of Death Among Construction Machinery Operators, Journal of Occupational Medicine(JOM), Vol. 19, pp. 123-128, 1977.

Dickie, D.E. Crane Handbook, Construction Safety Association of Ontario, Toronto, 1975.

Dickie, D.E. Rigging Manual, Construction Safety Association of Ontario, Toronto, 1975.

Gottlieb, M.S. Discussions of Topical Areas in Crane and Hoist use Safety, Wisconsin Department of Industry, Labor and Human Relations, Madison 1978.

Hagglund, G. Causes of Injury in Industry - The "Unsafe Act" Theory, University of Wisconsin - Extension, Madison, 1976.

Margolis, B.L., W.H.Kroes, R.P. Quinn. Job Stress: An Unlisted Occupational Hazard, JOM, Vol. 16, pp. 659-661, 1974.

Putz, V.R., B.L. Johnson, J.V. Setzer. Effects of CO on Vigilance Performance, HEW Publication No. (NIOSH) 77-124, 1976.

Quinn, A.E. Cranes, Lifting Machinery, Tackle; from the Encyclopedia of Occupational Health and Safety, pp. 345-347, McGraw Hill, 1974.

Repko, J.D., B.B. Morgan, Jr., J. Nicholson. Behavioral Effects of Occupational Exposure to Lead, HEW Publication No. (NIOSH) 75-164, 1975.

Rothe, M.A. Social Tracking in Children as a Function of Age, Masters thesis University of Wisconsin, Madison, 1973.

Smith, K.U. Interservice Conferences on 1) Systems Approaches to Risk Management and Improved Design of Worker's Compensation and Rehabilitation Programs and to Modernization of Industrial Safety and Health Concepts and Practices, and 2) Evaluating their Interrelated Performances by Behavioral Cybernetics Systems Concepts and Practices, Wisconsin Department of Industry, Labor and Human Relations, Madison, 1975.

Smith, K.U., and J.P. Henry. Cybernetic Foundations of Rehabilitation, Am. Jour. of Physical Medicine, Vol. 46, 1966.

Smith, M.J., H.H. Cohen, A. Cohen, and R.J. Cleveland, On-Site Observations of Safety Practices in Plants with Differential Safety Performace, HEW Publication (NIOSH) 1978.

Stellman, J.M. Current Concepts in Standards Setting - are they Working, Professional Safety, August, 1977.

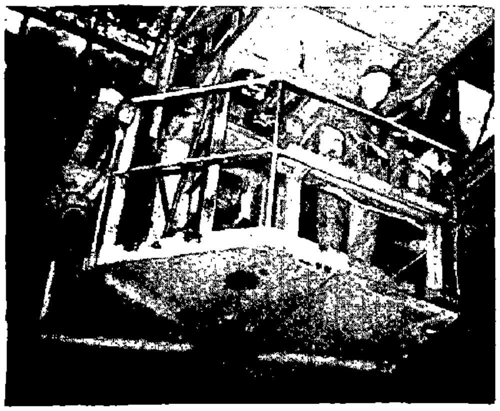
Swain, A.D. The Human Element in Systems Safety, Industrial and Commercial Techniques Ltd., London, 1974.

White, T.G. Ergonomic Survey of Mobile Cranes, Applied Ergonomics, June, 1973.

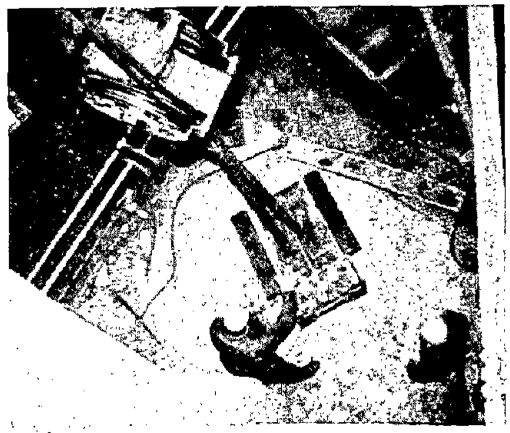
Xintaras, C., B.L. Johnson, I. deGroot. Behavioral Toxicology - Early Detection of Occupational Hazards, HEW Publication No. (NIOSH) 74-126, 1974.

A PICTORIAL SUMMARY OF CRANE AND HOIST HUMAN FACTORS RELATED TO SAFE OVERHEAD MATERIALS HANDLING

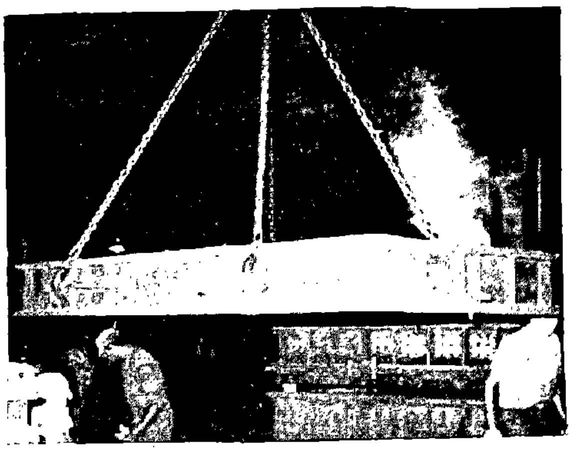
The following four pages present a brief summary of some of the critical aspects of human factors involved in the safe usage of cranes and hoists. The organization of these photographs roughly parallels the discussion of topics in Part IV of this chapter. Plates 1 thru 7 relate to issues involved in the operation of cranes and hoists and factors related to the crane and hoist operators control of overhead lifting safety. Plates 8 thru 10 point out some of the hazards and control factors related to the functions that load hitching personnel perform in crane or hoist operation. Plates 11 thru 17 illustrate problems and hazard control mechanisms related to the mechanisms for attaching loads to be lifted to cranes and hoists. The final group of plates (18 thru 22) point out some of the design and match of machine to task usage factors our study found important to safe crane and hoist operations.



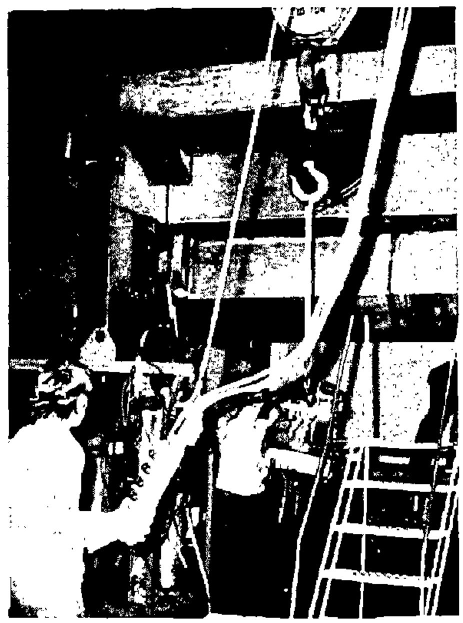
#1▲ THE LOCATION OF A CRANE OR HOIST OPERATOR'S CONTROL STATION AFFECTS A VARIETY OF FACTORS IN SAFE OVERHEAD LIFTING - WHICH RELATE TO THE WAY THE CRANE OR HOIST IS OPERATED.



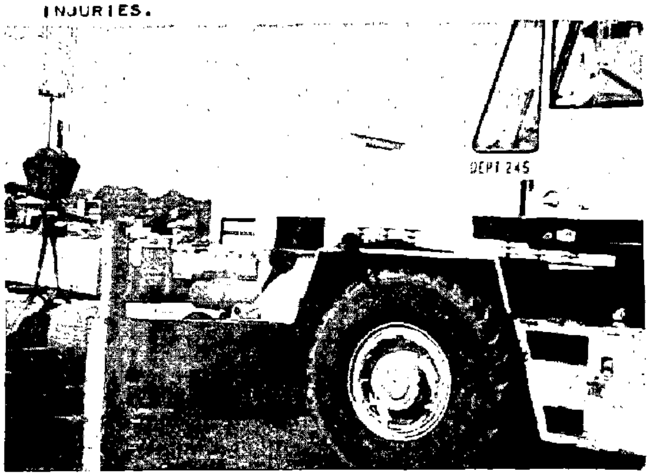
#2 ▲ THE OPERATOR'S LOCATION SHOULD ALLOW , AS MUCH AS POSSIBLE, A CLEAR VIEW OF THE LOAD, AS WELL AS A CLEAR VIEW OF WORKERS AND OBJECTS AROUND THE LOAD.



#3▲ CRANE AND HOIST INJURIES OFTEN HAPPEN WHEN LOADS SLIP AND FALL ON WORKERS, AND WHEN MOVING LOADS COLLIDE WITH WORKERS OR OTHER OBJECTS - CAUSING AN INJURY. BY NOT MOVING LOADS OVER WORKER'S HEADS, AND CAREFULLY CHOOSING LOAD PATHS OPERATORS CAN AVOID INJURIES.



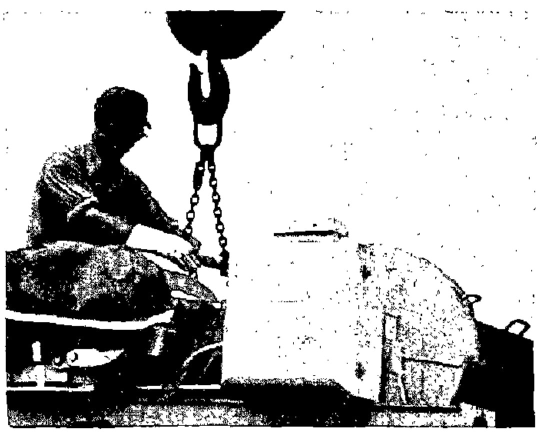
#4▲ FLOOR CRANE OPERATORS OFTEN HAVE THEIR VISION OF LOADS, OR WORKERS AROUND LOADS OBSCURED BY LARGE OBJECTS IN THEIR WORK AREA OR BY THE RAISED LOADS. SOME OPERATORS OF PENDANT CRANES COMPLAINED OF DIFFICULTY IN PRECISELY CONTROLLING CRANE DRIVE AND BRAKE CONTROLS.

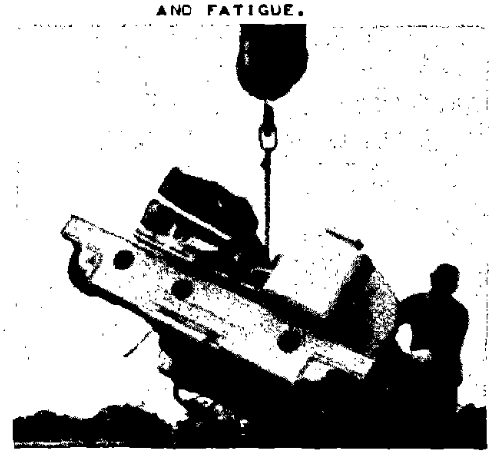


#5◀ MOBILE CRANE OPERATORS MUST BE SURE THAT THE LOADS THEIR CRANES LIFT ARE WITHIN THE CAPACITY OF THE CRANE FOR THE BOOM LENGTH AND BOOM ANGLE USED. CRANE SUPPORTS, LIKE THIS OUTRIGGER, MUST BE FULLY EXTENDED AND REST ON A FIRM SURFACE TO ASSURE PROPER SUPPORT.

#6 ▲ THE AREAS WHERE CRANES AND HOISTS MOVE LOADS SHOULD BE AS FREE OF DEBRIS AND TRIPPING HAZARDS AS POSSIBLE. A NUMBER OF INJURIES FROM MOVING LOADS WITH CRANES AND HOISTS INVOLVED WORKERS TRIPPING OVER DEBRIS WHILE CONCENTRATING ON RAISED LOADS.

#7 ▲ CRANE AND HOIST OPERATORS AND THEIR ASSISTANTS OFTEN WORK IN AREAS WHERE THEY ARE EXPOSED TO TOXIC FUMES. THESE FUMES ARE NOT ONLY A HEALTH HAZARD FOR THE WORKER, THEY CAN ALSO CAUSE STRESS AND FATIGUE.

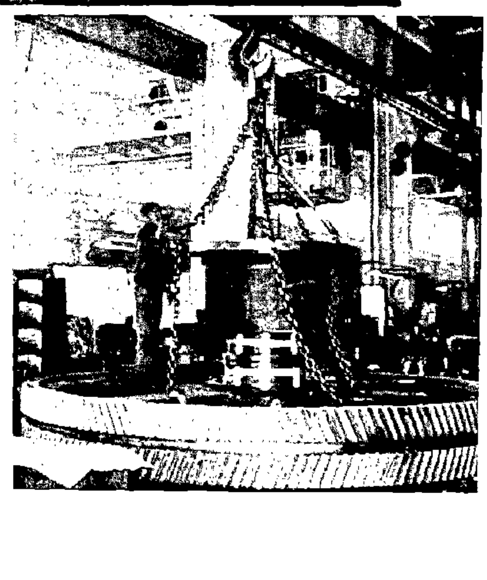


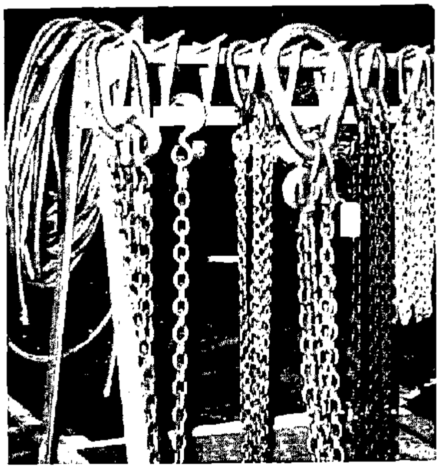


#8 ▲ LOAD HITCHERS OFTEN HAVE TO HOLD SLINGS WHILE THEY ARE BEING TIGHTENED TO MAKE SURE THEIR HOOKS SET PROPERLY. THESE WORKERS AND CRANE OPERATORS WORKING WITH THEM SHOULD BE CAREFULL TO AVOID GETTING THEIR FINGERS CAUGHT IN THE SLINGS OR THE SLINGS AND THE LOAD.

#9 ▶▲LOADS ARE MOST LIKELY TO SWING OR FALL FROM THEIR ATTACHMENTS WHEN FIRST LIFTED, FOR THIS REASON WORKERS SHOULD TRY TO STAY CLEAR OF LOADS WHEN THEY ARE LIFTED.

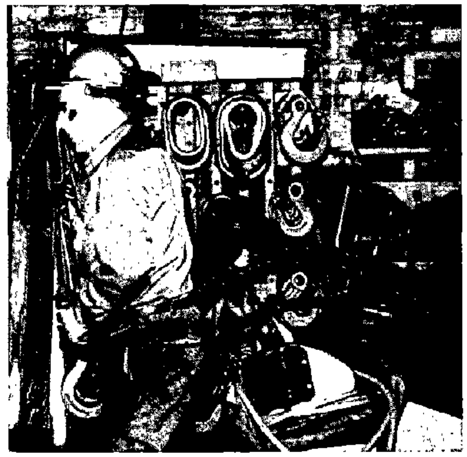
#10 ▶ THE COMMUNICATIONS BETWEEN THE LOAD HITCHER AND THE CRANE OPERATOR ARE VERY IMPORTANT TO LOAD HANDLING SAFETY. THEY SHOULD HAVE A CLEAR VIEW OF EACH OTHER, AND/OR AN EFFECTIVE SIGNAL SYSTEM TO TRANSMIT LOAD LIFTING INFORMATION.





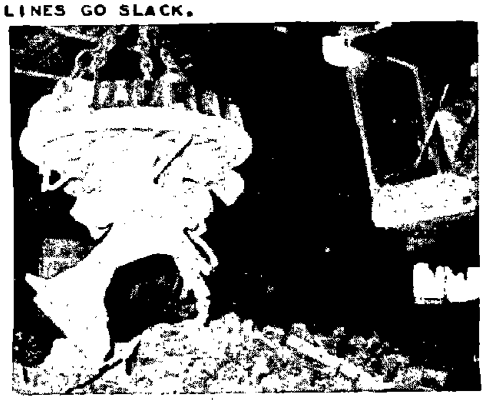
#11◀ A VARIETY OF SLINGS AND SLING MATERIALS ARE USED FOR LOAD ATTACHMENT IN OVERHEAD LIFTING. HITCHERS CAN SELECT THE PROPER SLING MOST EASLY WHEN THEY ARE NEATLY STORED ON A RACK, AS ABOVE.

#12▶ BY KEEPING A SUPPLY OF SLING COMPONENTS ON HAND A COMPANY CAN DESIGN AND BUILD SLINGS TO FIT THEIR NEEDS. THIS TYPE OF SLING FABRICATION SYSTEM CAN ALSO HELP A SLING INSPECTION AND REPLACEMENT PROGRAM.

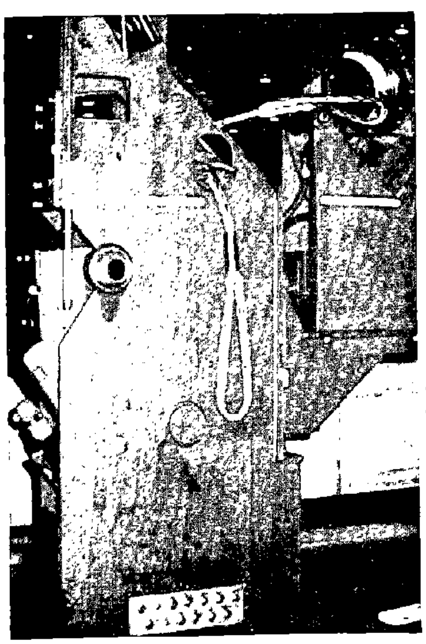


#13▲ ALL SLINGS CAN GET DAMAGED BY IMPROPER USE OR STORAGE. WORKERS WHO USE SLINGS SHOULD BE TRAINED TO STORE SLINGS PROPERLY, USE SLINGS TO AVOID CAUSING DAMAGE, AND INSPECT SLINGS FOR DAMAGE BEFORE USING THEM. WORKERS NEED TO BE SUPPLIED WITH THE RESOURCES TO PERFORM THESE TASKS.

#14◀ A NUMBER OF SPECIAL DEVICES ARE USED TO ATTACH OR ATTRACT LOADS TO BE LIFTED. THIS CLAMP AND OTHER GRAB TYPE DEVICES ARE FREQUENTLY USED TO GRASP LOADS. THESE NEED SPECIAL MAINTENANCE TO KEEP WORKING PROPERLY. THE CLAMP SHOWN ABOVE IS HAZARDOUSLY ATTACHED TO THE HOIST HOOK, IT CAN EASLY SLIP OFF THE HOOK IF THE HOIST LINES GO SLACK.



#15▲ THIS MAGNET NEEDS TO BE REGULARLY CHECKED TO BE SURE IT'S POWER CABLES ARE IN GOOD CONDITION AND IT'S ATTACHMENT RINGS AREN'T WORN.

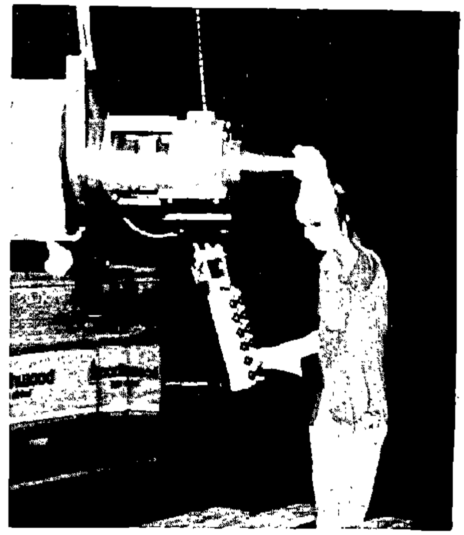


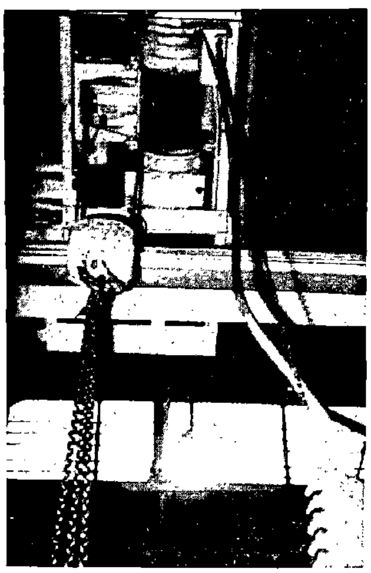
#16◀ TO MORE EASLY ATTACH ODD SHAPED LOADS, THESE LOADS CAN BE DESIGNED WITH SPECIAL HOLES OR GRAB POINTS FOR THE ATTACHMENT OF SLINGS.

#17▶ ONE FREQUENT CAUSE OF CHAIN DAMAGE IS WELD BURNS FROM ARC WELDING DONE WHILE SLINGS ARE STILL ON LOADS. THIS KIND OF PITTING CAN CAUSE THE METAL TO CRYSTALIZE AND LEAD TO A LINK FAILING.

#18 ◄ OUR STUDY FOUND THAT NO MAJOR DESIGN FLAWS EXISTED IN ANY OF THE CRANES OR HOISTS WE STUDIED. WHAT WE FOUND IS THAT LIFTING MACHINES AND THEIR CONTROL SYSTEMS MUST BE MATCHED TO THE TASKS THEY HAVE TO PERFORM.

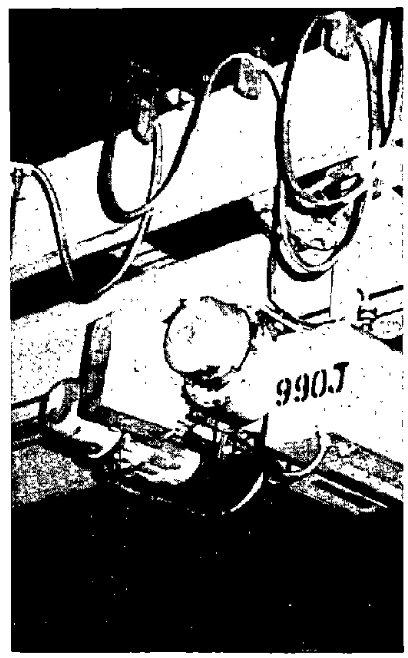
#19 ► ONE PROBLEM OPERATORS OF FLOOR-PENDANT OPERATED CRANES INDICATED IS HAVING TO STAND TOO CLOSE TO THEIR LOADS, AND HAVING TO HANDLE BULKY PENDANT CONTROL BOXES.





#20 ◄ MANY PENDANT CONTROLLED CRANES AND HOISTS HAVE PENDANT CORDS ATTACHED DIRECTLY TO THE HOIST MECHANISM. THIS LIMITS THE RANGE OF MOVEMENT AVAILABLE TO THE CRANE'S OPERATOR. THIS MAKES IT NECESSARY FOR THE OPERATOR TO REMAIN CLOSER TO THE RAISED LOAD THAN THEY OFTEN WANT TO BE.

#21 ► PENDANT CONTROLS FOR CRANES CAN BE ATTACHED TO CRANES BY LONGER CABLES WHICH RUN ALONG THE CRANE'S BRIDGE RAIL. THIS TYPE OF PENDANT ATTACHMENT ALLOWS THE OPERATOR MORE FREEDOM OF MOVEMENT AROUND RAISED LOADS.



#22 ◄ REGARDLESS OF WHAT TYPE OF CRANE OR HOIST IS USED ALL OF THESE MACHINES NEED TO BE REGULARLY INSPECTED FOR WEAR AND MALFUNCTION. THEY HAVE TO BE MAINTAINED IN TOP OPERATING CONDITION TO INSURE THEIR CONTINUED SAFE USE. EACH TYPE OF CRANE OR HOIST HAS SPECIFIC INSPECTION AND MAINTENANCE NEEDS DETERMINED BY ITS DESIGN AND THE WAY IN WHICH IT IS USED.

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CHAPTER 6. HUMAN FACTORS AND SAFETY CONSIDERATIONS OF CONVEYOR SYSTEMS

INTRODUCTION

Analyzing the human factor of conveyor systems is not a simple task, ideally or realistically speaking. The interaction between the working individual and a conveyor system represents a complicated network of physical and operational design considerations.

Our purpose in studying the human factors of conveyor systems was to identify various problem areas that are related to conveyor systems and to begin to provide directions for controlling these hazards.

This chapter represents the major findings of the conveyor portion of this study. A general statistical background concerning conveyor accidents is provided along with a section concerning the current status of conveyor related OSHA Standards. A theoretical discussion of relevant concepts that apply to the dynamics of conveyor operations is also contained in this chapter. The rest of the chapter deals primarily with major problem areas that were emphasized in the hazard information collected from workers, management, etc. A general summary and recommendations for controlling and preventing conveyor accidents is outlined.

Conveyor

> "A horizontal, inclined or vertical device for moving or transporting bulk material, packages, or objects in a path predetermined by the design of the device, and having points of loading or discharge, fixed or selective (American Natl. Std. B20-1972)."

"Conveyors are probably the most versatile labor saving device in industry. In its very earliest form - the chute - the conveyor predates the invention of the wheel. It is estimated that there are almost 100 types of material handling conveyors. The most common types include the belt, slat, apron, chain, screw, bucket, pneumatic, aerial, portable, gravity, live roll, vertical, magnetic, overhead and floor trolley." (Natl. Safety News, Feb. '77). Conveyors are often a component of other machines. Innovations created for particular job demands create an endless variety of conveyor systems. For the purposes of our study, only powered conveyors are included since their accident experience was rated higher than nonpowered conveyors. However, in most of the plants visited, the gravity conveyor was an integral part of the automated conveyor system.

Conveyors are used across industries for transporting materials and assembling operations. These uses vary from: handling bottles and castings (apron conveyors), acting as scrapers for stone, coal (flight conveyors), carrying hot, greasy metal parts, butchered meat (trolley conveyor), to mixing cement/sand mixtures, paint, etc. (screw conveyor).

Conveyor System

Unlike the crane and forklift material handling systems, the conveyor remains in a stationary position and is often a permanent fixture. The conveyor operator does not "control" the conveyor other than turning it on or off or perhaps controlling the speed (unlike cranes and forklifts where operator control is the crucial element in the system). There are instances where as much as 52 miles of conveyor can operate without a worker in the vicinity.

Therefore, the conveyor system is simpler than the crane and forklift system in that it requires less human involvement in its operation (including control and interactions). As a materials handling system, however, conveyors can by very complicated and complex pieces of machinery for moving material.

Conveyor Tasks--Job Design

Conveyor workers generally fall into two categories: production and maintenance. The production worker (who works at a conveyor) usually performs one of two major functions. The first is Assembling or performing an operation on the conveyed item (i.e., assembly line production). The second task involves Monitoring or watching for jammed materials, or inspecting material, while feeding or removing materials from the conveyor. The assembling and monitoring workers usually work at a fixed location or work station, unlike crane and forklift operators who must move with the flow of material.

Maintenance workers are another group that periodically work on conveyors performing regular or emergency operations.

People on conveyor systems are there largely to handle those tasks that machines cannot or at least do not do. This can be a rational use of human abilities, considering their remarkable visual perception and flexible manual output skills. There is little doubt that people excel at "straightening out the mess" and "keeping things moving in spite of". They are, in fact, too accomplished in exercising this adaptive flexibility. Too accomplished in the sense that they too easily exceed reasonable performance limits and thereby expose themselves to excessive accident potential. Unlike machines, which often simply stop or break if pushed beyond danger limits, people continue to perform, using a rather vast array of coping mechanisms. These mechanisms can be internal, information processing adjustments like selective omission, increased tolerance, increased errors, and temporary memory storage (Miller, 1964). They may also involve external, job related adjustments like reaching too far, too late in an attempt to prevent an errant part from jamming a machine.

BACKGROUND

This section concerns itself with the statistical analyses of information analyzed from the Employer's First Report of Injury, employee's report of the accident (Promptness Cards), and State Inspection Investigations. A discussion of conveyor related standards, both Federal and ANSI, is also provided.

Conveyor Statistics

The initial phase of the study involved analysis of conveyor related data. This data was obtained from three sources: Wisconsin Workers' Compensation Case History File, Wisconsin Safety Inspectors' accident investigations and promptness cards (mailed to every Workers' Compensation claimant who suffered an occupational injury involving four or more lost workdays during 1974. The cards contained a short questionnaire in post card format allowing the injured worker to describe how his/her accident occurred).

Analysis of Conveyor Related Promptness Cards

In investigations of 279 cases with conveyor implicated as a causal factor in 1974, the largest type of accident was caught in conveyor parts. There were 87 caught in conveyor cases reported accounting for 31% of conveyor accidents. Of the 87 cases, 37 occurred while employee was maintaining or unjamming the conveyor. Examples of this type of accident include: an employee replacing some part on the conveyor when another employee turned the conveyor on, or when an employee was trying to unjam something from the conveyor and the conveyor belt suddenly started up. Tables 6-1, 6-2. Thirty-five caught-in cases occurred while the employee was working at a conveyor line, loading, unloading packages, pushing items along the conveyor line. Fifteen cases were reported where it was undetermined what the employee was doing at the time of the injury.

Falls on or against conveyors accounted for 34 cases or 12% of the conveyor accidents. Examples of these conveyor accidents are (1) slipped on conveyor, (2) climbing over conveyor belt and (3) foot slipped off of framework dropping worker onto floor.

There were twenty-one cases (8%) where a worker bumped into or struck against a conveyor. An example of this type of accident occurred when a worker jumped over a conveyor track, slipped and hit his leg on conveyor.

In 12 cases, a worker was struck by conveyor part. In one instance, a worker injured his back when the arm of a faulty conveyor belt hook dropped due to vibration of rotating belts.

Sixteen percent of the conveyor accidents or 44 cases implicated material being handled on and around the conveyor. In four cases, workers were struck by moving objects on conveyors. These accidents indicate a pacing problem as employees were injured by material coming off the conveyor too fast. Twenty-two cases involved accidents where the employee was struck by objects falling from conveyor. These accidents resulted in bruises and cuts while loading and unloading material from the conveyor.

In nine other cases, workers were injured when they got caught between materials moving on conveyor; for example, getting hands or fingers caught between two boxes or cartons moving along the conveyor lines.

Overexertions in handling objects from conveyor totaled 57 cases or 20%. These accidents were most likely to occur from repeated motion of lifting heavy material on or off conveyor belt, or from jobs that require a lot of twisting and bending while loading or unloading the conveyor. There were thirteen cases that involved overexertion from handling the conveyor itself.

Table 6-1. Examples of promptness card cases involving conveyors.

Caught In

While maintaining conveyor;

1. Replacing plate in mold conveyor, another employee turned conveyor on causing plates to move together and pinch hand.

2. Installing chain on chip conveyor, finger caught between chain and sprocket.

Unjamming conveyor;

1. Employee was removing a piece of wood wedged between steel rollers and conveyor belt. After wedge was removed, conveyor belt started up due to faulty stop switch. Right hand was forced between two steel rollers, crushing hand. Prior to removing wood, employee pushed all stop buttons.

Working at line;

1. While loading, glove entangled in conveyor belt.

2. Pushing blocks from roller conveyor into box, hand slipped between conveyor belt and steel bar attached to the frame.

Fall Onto or Against Conveyor

1. Stepped on roller conveyor to remove cans, slipped on conveyor, bumped leg.

2. Climbed over conveyor belt, foot slipped off framework dropping worker about three feet onto concrete floor.

Bumped Into or Struck Against Conveyor

1. Jumped over conveyor track to release wedged cover, slipped, leg hit conveyor.

Struck by Conveyor Part

1. Faulty conveyor belt hook, arm dropped due to vibration of rotating belts, injuring back.

(Continued)

Pacing of Conveyor

1. Sliding packages into conveyor belt, they are only supposed to come one at a time but too many came at once, employee jumped back out of the way so feet wouldn't get caught, instead he fell over the edge of platform and was injured.

Struck by Moving Object on Conveyor

1. Ribs were against cars as assembly line started up resulting in broken rib.

Struck by Object Falling from Conveyor

1. Heavy metal object rolled off conveyor belt, object fell onto left foot. Object was four feet long and about 50 pounds.

Struck by Object Being Handled Onto/From Conveyor

1. Lifted large carton onto conveyor, it slipped out of worker's hand injuring hand.

Caught In Materials on Conveyor

1. Got finger caught between board that was coming down belt too fast.

Overexertion in Handling Objects from Conveyor

1. Repeated motion of lifting heavy boxes and carrying to conveyor belt.

2. Job required a lot of twisting and bending to pick cylinders off conveyor.

Overexertion Handling Conveyor Itself

1. Lifting conveyor, strained back.

Table 6-2. Total promptness cards with conveyor implicated as cause: 279 cases.

Major Groups of Promptness Cards		
Caught in Conveyor	87 cases	31%
while maintaining, unjamming	37 cases	
while working on line	35 cases	
undetermined	15 cases	
Fell On or Against Conveyor	34 cases	12%
slipped and fell against	16 cases	
fell when stepped on or against	18 cases	
Bumped Into or Struck Against	21 cases	8%
Struck by Conveyor Part	12 cases	4%
Struck by Moving Object on Conveyor	4 cases	1%
Struck by Object Falling from Conveyor	22 cases	8%
Struck by Object Being Handled from Conveyor	9 cases	3%
Caught in Materials on Conveyor	9 cases	3%
Overexertion in Handling Object from Conveyor	57 cases	20%
Overexertion in Handling Conveyor Itself	13 cases	5%
Other Miscellaneous	11 cases	4%
Total	279 cases	99%*

*does not equal 100 due to rounding

Summary Of Accident Investigations By Wisconsin Safety And Buildings Inspectors

A total of 386 accident investigation cases involving conveyor accidents during the period from 1972-1976 were analyzed. These accidents were analyzed according to the following factors; type of accident, source of of accident, causal factors and other factors. Most of the accidents occurred when the injured became caught in the conveyor (221 cases). Often these accidents occurred when the injured attempted to unjam the conveyor (43 cases), when cleaning the conveyor (38 cases), or when performing some type of maintenance on the conveyor (38 cases). Many of the accidents (97 cases) occurred while the injured was working at the line (unloading or loading conveyor, etc.). Table 6-3.

Several specific conveyor parts were involved in a number of cases. The sprocket and chain was the source of 28 accidents, belt and pulley (25 cases), belt and roller (18 cases), rollers (18 cases) and augers (13 cases).

Many of the accidents were due to lack of proper guarding (110 cases or 28%) or employe neglecting to shut off conveyor when unjamming or maintaining it (61 cases or 16%).

Other factors involved in conveyor accidents include getting gloves caught in conveyor (23 cases). This can happen as a result of improper fit of gloves. Lack of training was mentioned as a contributing factor in some cases. Other causal factors include slipping and tripping on or near conveyors, loose clothing (sleeves), workplace layout and speed stress.

Violations of safety standards (primarily improper guarding) were involved in 142 (37%) out of 386 accidents investigated.

Conveyor Fatalities

There were six (6) fatal conveyor accidents in Wisconsin from January 1972 to August 1976. There was one accident each year except that two accidents occurred in 1974. Two accidents involved becoming caught between belt and roller, one case involved becoming caught in a screw conveyor, one accident involved a fall from a conveyor, in one case a worker was caught between a dry block elevator and the dry block conveyor and in one accident the worker was dragged by a stacking conveyor and buried in a hopper.

All six accidents occurred when the employe was performing some type of maintenancing operation (unjamming, etc.). Only one of the six accidents resulted in a safety violation being written.

Table Descriptions

A cross tabulation of conveyor accidents within three digit SIC classification by type of injury is found in Table 6-4. All Wisconsin Worker's Compensation reported injuries from 1971-1975 were included in this analysis.

Table 6-3. Summary of investigated conveyor accidents. 1972-1976.

Total number of investigations	386	
Most frequent type of accident:		
Caught in while performing normal job	221	57%
Unjamming	43	11%
Cleaning	38	10%
Other maintenance	38	10%
Working at line (loading, unloading, etc.)	97	25%
Most frequent source of accident:		
Sprocket and chain	28	7%
Belt and pulley	25	6%
Belt and roller	18	5%
Rollers	18	5%
Auger	13	3%
Conveyor nec.	21	5%
Causal factors:		
No guard	110	28%
Employe didn't shut conveyor off	61	16%
Employe tripped, or slipped around conveyor	28	7%
Gloves (too large, got caught in conveyor)	23	6%

Table 6-4. Top 20 industries with conveyor injuries by type of injury 1971-1975.

S.I.C.	Rank #	Accidents	%	Caught In	Caught In Mech. Parts	Falls Other	Falls Same	Over-exertion	Over Handling	Over Push.	Over Lift	Struck St. Obj.	Struck Mater.	Struck Mov.	Struck Tip	Struck
Food Etc.	1	332	21	20	129	3	34	1	5	4	8	71	32	8	5	12
Fab. Metal	2	119	7.4	3	35	1	11		1	3	4	29	23	2	2	5
Prim Metal	3	116	7.2	12	37	2	9		2	2	2	16	18	4	1	11
Mach. Ex. Elec	4	114	7.1	7	27	4	13		5	3	4	18	14	1	8	10
Paper	5	101	6.2	12	52		9			2	3	10	5	1	2	5
Lumber	6	92	5.7	8	45		7		1	1		11	15	2	1	1
OTR Retail	7	79	4.9	6	25		8			4	4	14	8	2	5	3
Whole Non	8	68	4.2	7	25	2	3		2		7	5	5		4	8
Agrig.	9	63	3.9	5	30		4			4	4	6	2		1	7
Trans. Equip	10	56	3.4	5	15	1	3			2		7	15	2	1	5
Elec. Equip	11	45	2.7	2	14		2		2		3	15	5	1		1
Whole Dur	12	39	2.4	4	13	1	5		2		3		4	2	2	3
Trucking	13	38	2.3	5	20		2		1	2	1	3	2	1		1
Furniture	14	34	2.1	1	10		3				1	11	6			1
Other Serv.	15	32	2	1	14	1	3		1	1	3	4	3			1
Stone, Glass	16	29	1.8	2	15		3					5	1		1	2
Pub. Adm.	17	27	1.6	1	8		2		1		1	5	4	1	1	3
Auto Repair	18	25	1.5	4	21											
Rubber	19	21	1.3		12		2		1			4	1			
Mining	20	20	1.2	3	9		1				1		1	2		3
Other		159	9.8	15	62	4	9			3	8	24	18	2	2	9
Total		1,609		123	618	19	133	1	24	32	57	258	182	31	36	91
Percent				7.6	38.4	1	8.2		1.4	1.9	3.5	16	11.3	1.9	2.2	5.6

Industries are ranked according to number of accidents within a SIC grouping. The vertical "%" column represents the total percent of conveyor accidents that fall within a given industry.

As shown in the table, the Food Industry by far accounts for the largest number of conveyor accidents (332 accidents) as well as the highest percentage of conveyor accidents (21%) as compared to the total number of conveyor accidents in Wisconsin from 1971-1975. In the Food Industry, caught in mechanical parts and struck by stationary objects represents the major types of conveyor accidents. These two types account for 60% of the conveyor accidents in this industry. Ranked below the Food Industry in number of conveyor accidents are the Fabricated Metal, Primary Metal and Machinery except Electrical Industry groups. These three industries each account for about 7% of the total number of conveyor accidents from 1971-1975. In the Fabricated Metal Industry group, ranked number two, caught-in accidents accounted for 37 accidents while struck by stationary object and struck by material accounts for 52 accidents (44% of this industry's conveyor accidents).

Due to limited data available, it is not known at this time whether the high number of conveyor accidents are a function of industries with high conveyor usage or high numbers of workers in contact with conveyors.

A cross tabulation of conveyor accidents within three digit SIC classification by source of injury is found in Table 6-5. This table represents reported conveyor injuries from 1971-1975. The primary sources of conveyor injuries are conveyor n.e.c. (not elsewhere classified) (60%) and belt conveyors (20.3%).

Conveyors placed in the category of conveyor n.e.c. are unspecified on accident reports at the time the accident is coded. It is assumed that a large proportion of conveyor n.e.c. accidents involve belt conveyors since belt conveyors are most commonly used.

Table 6-6 represents a cross tabulation of type of accident by source of conveyor. The four major combinations of conveyor accident types as represented by this table are: (1) caught in conveyor n.e.c., (2) caught in belt conveyor, (3) struck against conveyor n.e.c., and (4) struck by conveyor n.e.c.

Differences in totals between these three tables can be explained by different time periods and different coding groups for the computer listings that were obtained.

Statistical Overview

An analysis of 1,609 conveyor accidents for 1971 through 1975 indicated that being caught in the mechanical parts of the conveyor was the most frequent type of accident (46%). Being struck in various ways by either material on the conveyor or the conveyor itself constituted the second major category (37%). Falls involving conveyors (9.2%) and overexertion (7%) were the least frequent types of conveyor accidents.

Table 6-5. Top 20 industries with conveyor injuries by source 1971-1975.

S.I.C.	Accidents	%	Belt	Chain	Gravity Roller	Monorail	Overhead Trolley	Pallet	Screw	Mobile Elevator	Conveyor NEC	Other
Food Etc.	336	21	67	15	12	1	2	2	7	1	204	6
Feb. Metal	120	7.3	11	7	8		3				89	2
Prim. Metal	117	7.2	13	2	13	2	8	1		1	76	1
Mach. Ex. Elec.	115	7	10	4	9		3		2	2	81	4
Paper	101	6.2	26	3	9				2		61	
Lumber	93	5.7	22	4	9				1		57	
OTR Retail	80	4.9	22	3	5					6	42	2
Whole Non	71	4.3	13	3	2		1			19	32	1
Agris.	63	3.9	13	4				1		19	26	
Trans. Equip	56	3.4	4		3	1					46	2
Elec. Equip	45	2.8	10		3		1				30	1
Whole Dur.	39	2.4	8	1	1					7	22	
Trucking	38	2.3	17		3					4	14	
Furniture	34	2	4		4			1			25	
Other Serv.	33	2	13							2	16	2
Stone, Glass	29	1.8	10		3			1			15	
Pub. Adm.	27	1.6	6	2			2			2	12	3
Auto Repair	25	1.5	3	2	8						12	
Rubber	22	1.3	6	1	3	1					11	
Mining	20	1.2	8								12	
Other	160	9.8	45	3	7	1	3	1		1	95	4
Total	1624		331	54	102	6	42	7	12	64	978	28
Percent			20.3	3.3	6.2	.03	2.5	.04	.07	3.9	60	1.7

Table 6-6. Conveyor Source by Type of Accident. (1972-1975)

Type	Total	Belt	Chain	Mono-Rail	Overhead Trolley	Pallet	Screw	Auger	Mobile Elevator	Conveyor NEC	Other Conveyers
Total	1255	293	38	4	36	7	10	2	49	806	10
Falls	127	12	1	0	1	1	0	0	3	108	1
a. Falls on same level onto or against	105	10								95	1
Struck Against	228	20	1	1	3	1	1	0	4	196	1
a. Stationary object bumped into	205	16	1	0	3	1	1	0	4	179	1
Struck By	242	23	1	1	20	2	0	0	15	178	2
a. Tipping, sliding, rolling object	27	4	0	0	0	0	0	0	3	20	
b. Moving part of equipment	24	3			5				1	15	
c. Material from equipment	133	14		1	10				1	107	1
Caught-In	551	234	32	1	6	3	8	2	16	244	5
a. Mechanical apparatus or parts	445	208	30	1	5	2	7	2	11	179	4
Overexertion	97	4	3	1	2	0	1	0	10	75	1
a. Lifting, lowering	50	1	1						5	43	
b. Pushing, pulling	30	2	1		1				3	23	
c. Handling	15		1	1	1		1		2	9	1
Other	10	0	0	0	4	0	0	0	1	5	0

Insurance promptness reports and state inspectors' accident reports were a subset of these conveyor accidents. An analysis of these nondetailed sources of information revealed trends in causal factors implicated in the etiology of these accidents. Specifically, caught in conveyor accidents either occurred while the injured was unjamming or in some way clearing the conveyor, or the injured was working at the line performing his/her normal duties. The most frequent caught in nip sources were sprocket and chain, belt and pulley, and belt and roller. The main reason for the accidents (as determined by inspectors' reports) was that a guard was lacking on the conveyor. The second most critical factor indicated that the employe failed to shut the conveyor off when he/she should have. The final categories consisted of the employe tripping or slipping into nip points of the conveyor and having large gloves or other apparel items catch and drag the employe into the conveyor.

Standards

In the area of standards regulation, the Federal guidelines for conveyor systems are very limited.

While there are several standards that have provisions for conveyors (Spray Finishing 107(b)(7), (h)(7); Dip Tanks 108 (c)(6); Cooperage Machinery 214 (o); Pulp, Paper and Paperboard Mills 261(c)(15)(16); and Forging Machines 218(j)(3); Bakery Equipment 263(d)(7), (i)(7); and Sawmills 265(c)(18))(OSHA Standards 1976), these are related to very specific machines and conveyor components; generally geared toward guarding considerations. Presently, there is no standard that has been promulgated by the Occupational Safety and Health Administration to cover all conveyors and their operations, (although one is being proposed as of the date of this writing). The standards mentioned in 1910.212 (General Requirements for all Machines) and 1910.219 (Mechanical Power Transmission Apparatus), while not written specifically for conveyors, are very relevant to conveyor systems. They address many of the issues of guarding, exposed nip points, moving gears and machinery, etc. In fact, based on an analysis of Wisconsin Inspectors' Investigations (years 1974-77), these two standards were cited more frequently in relation to conveyor accidents than any of the other standards specifically mentioning conveyors. Out of 80 citations, 1910.219 and its various subsections were cited a total of 23 times; 1910.212 and its subparts were cited 42 times. Various other standards were cited once or twice.

Regarding the citation of specific conveyor standards by OSHA inspectors, data was obtained on the frequency that these standards were cited in the Chicago area along with the relative dollar amount for each citation, Table 6-7. As can be seen from this table, the OSHA standards specifically related to conveyors are cited very infrequently. Counts for 1910.212 and 1910.219 standards are not given, since there is no way of knowing specifically how many violations are related to conveyors. It is felt, however, that as was true with state inspections, these two standards would also be implicated in many of the Federal citations of conveyors.

Table 6-7. Standards Cited in the Chicago Region October 1976-March 1977.

Conveyor Standards	Serious Violation	Nonserious Violation	Total Violations	Total Penalties ($)
1910.107(b)(7) Spray Finishing	--	--	--	--
1910.107(h)(7) Spray Finishing	--	--	--	--
1910.108(c)(6) Dip Tanks	--	1	1	30
1910.214(o) Cooperage Machinery	--	--	--	--
1910.218(j)(3) Forging Machines	--	--	--	--
1910.261(c)(15) Pulp, Paper Paperboard Mills	--	2	2	--
1910.261(c)(16) Pulp, Paper Paperboard Mills	--	1	1	--
1910.263(d)(7) Bakery Equipment	--	--	--	--
1910.263(i)(7) Bakery Equipment	--	--	--	--
1910.265(c)(18) Sawmills	--	1	1	--

The American National Standards Institute (ANSI) has developed a rather complete set of standards for conveyors (ANSI B20.1--'76) and this has been adopted in part in some of the conveyor related OSHA standards. In addition, according to information received during this project, in certain instances, specific manufacturers of conveyors and companies that use conveyors have also incorporated the ANSI standard into the design of their conveyor systems.

The safe operation of conveyor systems requires that certain physical standards, e.g. guarding be met. In conjunction with this, and just as important, are behavioral or operational requirements that must be followed by individuals who work at and around conveyors. The following conveyor standards are among ANSI B20.1--'76R standards that refer to behavioral requirements. These behaviors include utilizing trained, qualified personnel in certain operations, setting up maintenance programs, prohibiting riding on conveyors and stopping conveyors before working on them, etc. (5.02.1, 5.02.2, 5.02.3, 5.02.4, 5.02.5, 5.02.6, 5.03.1, 5.04, 5.11.4.2, 5.12.1, 5.12.2, 5.12.4, 5.12.5, 5.12.8, 6.01.2.1, 6.04.3.1, 6.11.1.2)

SOCIO-TECHNICAL ASPECTS

The following section contains a discussion concerning the interaction of social and technical factors related to conveyor systems.

Socio-Technical Systems Design

Socio-technical systems theory is concerned with any organizational setting in which humans combine their efforts in cooperative activity with technology toward the achievement of a goal. Therefore those workers who work on or around conveyors as well as the conveyor hardware are components in the socio-technical system.

The system is viewed as operating within and interacting with its environment. It receives inputs, alters them and exports outputs to that environment. For example: A conveyor receives materials or packages, processes or performs operations on them, and material is moved out of the conveyor system.

In socio-technical systems, independent technical and social systems operate and interact jointly. This leads to the central concept of joint optimization, which states that when achievement of a goal depends on independent but correlated systems such as conveyor hardware and conveyor operations, it is impossible to design for optimal performance without seeking to optimize the correlative systems jointly. (Davis, 1972) Therefore, the conveyor system must be designed to allow for the optimum performance of both workers and the machine.

In terms of optimal human performance, design of conveyor based work systems is predominantly concerned with the physical and operational task factors encompassed within the limits of human ability. In addition, design of psycho-social needs for self-satisfaction is necessary for worker attention and motivation.

Optimal performance of the technologic or machine aspect of the socio-technical system is directed towards minimizing shutdown time (and hence maintenance), speed or maximization of production flow, and minimizing the processing cost per unit of production.

The joint optimization of these two sets of factors thus constitute the efficient production achievement goal of the conveyor based socio-technical system.

Variance--

> "Humans in automated systems are interdependent components required to respond to stochastic, not deterministic conditions, i.e., they operate in an environment whose 'important events' are randomly occurring and unpredictable. In production systems, stochastic events have two characteristics; unpredictability as to time and unpredictability as to nature. For economic reasons, they must be overcome as rapidly as possible, which imposes certain requirements on those who do the work. First, the workers must have a large repertoire of responses or skills, because the specific intervention that will be required is not known. Second, they cannot depend on supervision because they must respond immediately to events that occur irregularly and without warning. Third, they must be committed to undertaking the necessary tasks on their own initiative." (Davis, 1972) (Additional discussion of variance is found in Chapter 2.)

Conveyor Accidents and Variance Effects--

Variance effects are unprogrammed events that critically effect outcomes. Like stochastic conditions, variance effects are often events that workers have limited control over, and require unusual actions on the part of the worker. These events seem to be implicated in a large number of conveyor accidents. For example, caught-in accidents make up the largest number and percentage of conveyor accidents. Unjamming materials is the largest type of caught-in accident. Since jammed materials are unprogrammed events, the operation of unjamming is often unexpected. Furthermore, employes may not be trained in safe unjamming procedures.

Another variance effect related to conveyor accidents occurs when a worker has shut off the conveyor to maintenance it, and another worker, unaware of the actions of the first worker, turns the conveyor on or starts it unexpectedly.

Varying the materials conveyed can result in several problems. The conveyor may not have been designed to convey these items. Materials may fall off or strike workers. Workers might utilize a new set of movements to compensate. Other variance effects may result from workers whose job is changed and are unfamiliar with the operation and stop buttons, etc. Speedups to meet production quotas also produce a variance effect on the worker.

The workplace layout may encourage workers to assume unplanned or unprogrammed actions. For example, the location of a conveyor work station may not create easy access to other work areas. Therefore, workers are injured when climbing over or under conveyors. This indicates that one type of variance may lead to another and so on.

It appears that variances are a factor in the majority of conveyor related accidents.

Variance Control--

Variance control is an important tool in current socio-technical analyses (see Engelstadt in Davis and Taylor, 1972 for an example). It takes the stand that the important roles for people in productive systems are in reducing (controlling) deviations (variances) from regular, expected operations. (Looked at the other way, it suggests that if variances do not occur the process is ripe for machine handling.) Reducing variances seems a useful way of viewing much conveyor work, particularly if an extension to include loading and unloading varying size and shape items is allowed. The fundamental concept in current socio-technical theory (Cherns, 1977) is to place the control of variance as near as possible to its source or generating point--ideally with the same person or at least group responsible for the source. Thus, for example, the person responsible for straightening out items or sorting out defects on a conveyor should have, or be a member of a group that has, responsibility for the machine whose process produces the nonuniform array of defects. Passing variance across departmental lines or architectural barriers (e.g. through walls) is obviously poor design. The configurations which might follow from this design principle are, of course, totally dependent on the specifics of the plant, process, and product.

New technology requires a high degree of commitment and autonomy on the part of the workers in automated production processes. Organizations are far more dependent on the individual (although there may be fewer individuals) in automated systems. (Louis, 1972).

Conveyor Operations Safety--Control, Constraints, Variance--

A system is made up of interacting components. Each component possesses control over certain factors while being constrained by other factors.

As Table 6-8 illustrates, management has control over most factors in the workplace in regard to safety. Management makes decisions regarding physical aspects of the workplace, design of equipment, and personnel as well as general production management. Management operates under technological financial constraints and labor markets. Workers' control is constrained by the factors that management controls since workers seldom have input in these matters.

Certain "unprogrammed events" or variances occur which can create hazardous conditions. These events include machine malfunctions, human behavior, speedups, irregular-varying materials, etc. Management has control over these factors to some extent, e.g. management controls speedups, irregular/varying materials, job placement and training and selection, supervision of workers, preventive maintenance programs, etc. Workers and management are constrained by material and equipment and their own past decisions and personal characteristics.

Social and Psychological Factors--

Unlike materials handling tasks such as driving forklifts or operating or hooking cranes, many conveyor related operations require the operator to remain in a stationary or fixed position with repetitive body movements. This job design may produce monotonous, fatiguing, boring work conditions that may result in lowering the workers' attentiveness to their tasks, perhaps increasing one's susceptibility to an accident in the event of an unexpected occurrence. Boredom may also prompt a worker to seek stimulus, thereby creating a hazard situation. (Mann, Hoffman, 1960)

During the course of our observations and interviews with those who work on conveyors, several social issues arose. Environmental conditions may range from an extremely crowded workplace with many workers on a line and lines close together to working on conveyors in isolation. Both social conditions produce potentially hazardous situations. While the social interaction allowed in crowded workplaces are desirable for most workers, the physically crowded conditions produce hazards. However, inability to communicate with co-workers due to noise or geographic isolation has been shown to be a factor in psychological disorders (e.g. group hysteria, depression). (Colligan, Smith, 1977) In cases of an imminent danger or accident, communication to prevent an accident or reach or assist an injured worker is restricted.

Another social-psychological phenomenon related to conveyors is the operator's lack of control over the pace of work. In most cases, management sets the pace of the conveyor and workers are forced to constantly work under speed stress. Speed stress may be an underlying factor in many conveyor related accidents. If speed stress wasn't present, many unjamming accidents would probably be prevented since operators, not being as rushed or pressed to keep lines going, would turn off the conveyor first, before reaching to remove a jammed item. Similarly, it seems that a large percentage of overexertion and struck-by accidents may also be reduced. Feelings of lack of control may also lead to alienation and apathy towards the job and possibly lower attention to tasks, producing a preaccident scenario.

METHODS

The following section describes the method utilized in collecting input from manufacturers, designers and users (management and workers) of conveyors.

Introduction--Conveyor Site Visits

In total, thirteen companies including two manufacturers were visited for the conveyor portion of the human factor's materials handling project.

Table 6-8. Control, Constraints, Variance--Conveyor Operations Safety.*

MGT. CONTROL	MGT. CONSTRAINTS	WORKER CONTROL	WORKER CONSTRAINTS	VARIANCES	CONTROL OF VARIANCES
WORKPLACE: layout temp. noise	OLD, INADEQUATE DESIGN CURRENT TECHNOLOGY $$	HAZARD AVOIDANCE BEHAVIOR	WORKPLACE	LAYOUT	MANAGEMENT
DESIGN OF EQUIPMENT: guards height location of controls	OLD, INADEQUATE DESIGN CURRENT TECHNOLOGY $$ DESIGN OF TOOLS	REPORTING HAZARDS	DESIGN OF EQUIPMENT	MACHINE MALFUNCTION	MANAGEMENT preventive maintenance programs
PERSONNEL: training experience selection	LACK OF AVAIL-ABILITY $$	EXPERIENCE: training skill	ADEQUACY OF SUPERVISION, MAINTENANCE PERSONNEL TRAINING	HUMAN BEHAVIOR JOB TRANSFERS	SELECTION TRAINING SUPERVISION
MANGEMENT DECISIONS: maintenance priority safety priority pace job design materials handled	TOP MANAGEMENT SIZE OF WORKFORCE $$		MGT. DECISIONS maintenance priority safety priority pace job design	SPEEDUPS IRREGULAR/ VARYING MATERIALS	MANAGEMENT

*This table is meant only to give examples of components involved in conveyor operations safety. It is not exhaustive

At the initial stages of the project, manufacturers of conveyor systems were contacted and visited in order to provide input regarding design and installation considerations of conveyors.

In five companies, management, supervisors and individuals who worked with and around conveyers were interviewed concerning factors related to conveyor operations. These included a corrugated paper company, a carbonated soda canning company, a brewery, a glass bottle manufacturer and a bakery. The selection procedure for these companies and the format of the site visit was similar to that previously described. (See Forklift Section.)

In addition, we were able to accompany several state inspectors on three investigations of conveyor accidents. The three investigations occurred at a packaged food plant, a canning company and a wood furnishing company.

Supplemental information was also obtained from three additional companies including a frozen foods bakery, a battery manufacturing plant and a plastic manufacturing industry. While no workers were actually interviewed in these three companies regarding conveyor operations, conveyor operations were observed, and the information collected was felt to be relevant for inclusion in this report.

A total of 58 workers in five plants were interviewed for their ideas and input to conveyor operations and related tasks. (Examples of the questions which were asked of workers/management involved in conveyor operations are shown in Appendix A.)

The occupational titles of these workers varied from plant to plant and were related to the specific conveyor line or machine they were working on, e.g. in the bakery individuals who were bun line operators, loaf molders, wrapper operators, were interviewed; in the beverage and brewery plants there were filler operators and depalletizer operators; in the corrugated paper plant there were feeders and stackers. In no company did we interview anyone who was known "per se" as a "conveyor operator." However, even though the occupational titles were quite different from plant to plant, the functions and job tasks related to these operations were quite similar. For example, most of the conveyor operations looked at required someone feeding or putting something onto a conveyor, removing something from a conveyor or guiding the product or material being conveyed. (This function of guiding the product, or performing something of an inspection task, was particularly the case in the canned beverage, brewery and glass industries.)

RESULTS

The following section entails the results of worker and management interviews as well as more specific comments regarding causal factors involved in conveyor accidents. These include hazard tables and explanation of various conveyor "accident types" (e.g. caught in, overexertion, falls, bumped into), equipment design, job design and training.

Custom Design and Conveyors

Prior to any actual industry site visits or interviews with workers, manufacturers of conveyors were contacted and visited in order to gain their insight on conveyor problems, and also to gain an understanding of the conveyor equipment that is being utilized in industry.

Based on information received from conveyor manufacturers and subsequent information obtained in conveyor site visits, it became obvious that, unlike forklifts and cranes, conveyors are often custom-designed for a company's needs. Components of the conveyor system such as chain, belt, etc. are usually purchased from several conveyor component manufacturing companies in the country.

A manufacturer may be responsible for designing, building and installing a conveyor system or may be involved in just one stage of this process. In certain instances a company will send their specifications to a conveyor manufacturer and have them design and build the system. Installation is another service that is left up to the purchaser.

According to one conveyor manufacturer, there are basically three major kinds of conveyors used in industry; the belt, screw and trolley conveyor. In addition, these are driven primarily by chain, V-belt or wire rope.

This conveyor manufacturer felt that many conveyor problems and injuries were due to poor or unscheduled maintenance. In the experience of this manufacturer, conveyors need three things: greasing at least once a month, aligning, and maintaining belt tension. If maintenanced properly and regularly, conveyors should last through 5--7-1/2 years of normal use; without maintenance this is reduced 3--5 years. Nine out of ten conveyors that this manufacturer later replaced were not properly or regularly maintenanced.

Training personnel regarding proper maintenance procedures is a service that is provided by the manufacturer to the buyer at an additional cost. Some companies employ maintenance companies to maintain their conveyors.

Guarding and lock-out systems are recommended by the manufacturer along with emergency stops located every 50 feet or in sight of the conveyor operator. These features, however, are up to the discretion of the purchaser. If the purchaser should decide not to install these features, the manufacturer makes the recommendation in writing and has the purchaser sign the refusal of recommendation. This is usually a safeguard (although no guarantee of protection) for the manufacturer should any questions or problems arise in the future that may be related to product liability cases.

The design of conveyors is almost always done <u>after</u> a building is built. Because of this, and because of the variety of uses for conveyors, there are probably no two conveyors which are exactly alike. This makes generalization on conveyor problems somewhat difficult.

Results from Worker Interviews on Conveyor Operations

Tables 6-9--6-13 represent hazard information that was collected through worker interviews. The tables are initially arranged by the major type of conveyor hazard that's indicated by the reported hazard (e.g. caught-ins, fall, bumped into, overexertions). These hazards were then placed serially in categories depending on the amount of control a worker had in effectively preventing the hazard from resulting in a serious problem (e.g. (1) hazards present in the workplace which the worker has minimal control over, (2) hazards related to preoperation tasks and (3) hazards related to task-specific functions). Within each of these classifications, hazards were organized into hazard categories that indicated a potential hazard or situation that the hazard related to e.g. guarding problems, inadequate maintenance, workplace design, etc. In certain instances the hazards reported were applicable in several of the hazard categories. When this was the case, the hazards were listed under appropriate categories. As a result, these categories are not independent or mutually exclusive of themselves.

Analysis of conveyor hazards reported by workers closely parallelled the information that was discerned from Worker's Compensation statistics, Inspectors' Investigations of conveyor accidents, and Injured's report of conveyor accidents (promptness cards).

Caught in conveyor type accidents represent the primary problem with conveyor systems, as indicated by the accident statistics and worker interviews.

Caught-In Type Conveyor Problems

Caught in conveyor type accidents are one of the primary problem areas associated with conveyor systems. Unguarded nip points and gears constitute a major concern for individuals who must work at or around conveyors. Interviews with workers indicated that sometimes guards are either inadequate or missing completely resulting in caught-in hazards. In other instances, maintenance may be slow in repairing or replacing a broken guard. Another factor that is appropriate to caught-in problems is the location or placement of control switches and stop buttons. Worker interviews often revealed that "stop" switches are not easily accessible from the work station. It was learned that on some conveyors the stop switch is located on the opposite side of the conveyor from where the worker is standing. In other cases workers reported that the controls were placed too high which was particularly a problem for shorter people. The location of controls is significant in emergency situations. For instance, a situation could develop where the item being conveyed jammed or a worker got caught in the conveyor. If stop buttons are out of reach, serious injury could result if the worker were not able to be freed quickly.

Loose clothing (sleeves, shirttails, gloves) can also create a caught-in problem. In some industries, workers must wear gloves that are too large or where they aren't properly fitted.

Scrap or clutter that accumulates on the floors, slippery floors, poorly designed platforms are several conditions that may be implicated in caught-in hazards. If the workplace is laid out so that the work station becomes cluttered with debris, workers may slip and fall into moving parts of the conveyor.

An operational behavior that is very important in conveyor related tasks concerns shutting off the conveyor prior to doing any work on the conveyor. This is particularly relevant to unjamming or emergency situations. Under these conditions, caught-in accidents can result in various ways. One of the most frequent of these occurs when the item or product being conveyed jams on the conveyor. This may be due to a defect in the product or a conveyor that isn't designed to adapt to various sizes or shapes that are to be conveyed. Speed stress or production pressure can also lead to jam-ups if a worker must perform at a pace that is not conducive to safe conveyor operations. In many instances, a worker's first reaction after a jam has occurred is to reach into the conveyor to try and free the item without first shutting off the power to the conveyor. Pulling on a conveyor belt or jammed item may cause the conveyor to suddenly start up, pulling the worker into the moving conveyor.

Another hazard arises when lock-out systems are not available to adequately shutdown a conveyor. Another side to this involves lack of communication between co-workers regarding shutdown procedures. Information obtained particularly from inspectors' investigations revealed that one worker not realizing a conveyor is shutdown for emergency or maintenance purposes may accidently turn the conveyor system on while another worker is attempting to repair the conveyor. Behaviors such as these can often produce a caught-in accident, especially in areas where workers are geographically isolated from one another. This is more of a problem in industries that are highly automated, requiring fewer workers to attend to the conveyor line.

Other caught-in accidents can result when workers are performing their normal duties on the conveyor (e.g. feeding something onto the conveyor, removing items from the conveyor, inspecting items as they are being conveyed).

If job functions are repetitious and monotonous (as is often the case with conveyor operations) alertness and attention to the task being performed may decrease. As an example, workers may put their hands in unguarded areas and a caught-in accident could result.

Overexertions

There are several conveyor features that encourage overexertion. These are related to the height of the conveyor or workplace. The height of the work-table or rollers may be too low requiring bending, thus leading to backstrain. The platform a worker stands on may not be of the correct height. Mechanized lifts for feeding stacks of materials into or from conveyors may be lacking. Inadequate maintenance also may contribute to overexertion, e.g. missing rollers, guide that feeds into conveyor is broken.

Other factors occurring during a conveyor task causing overexertions include: materials being stacked too high from a conveyor making subsequent manipulation difficult or hazardous. Lifting materials such as boxes or cartons used to package conveyed materials, lifting material on or off conveyor, bringing down a heavy motor on ladder when repairing overhead conveyor, unloading material from high stacks results in overexertion hazards. Pushing loads over conveyors may cause overexertion. This is particularly a problem when rollers are missing, pushing against "grain" of conveyor, pushing over walkplates. The process of feeding the conveyor may require constant bending, reaching, twisting or turning.

Falls

Falls account for another problem area that is connected with conveyor systems. The most common fall hazard results from oil leaks that remain on the floor creating a slipping hazard. Interviews with workers and maintenance personnel indicated that hydraulic systems are frequently the source of oil leaks on conveyors.

Wet and slippery floors are a particular problem in certain industries (e.g. food, beverages) because of the nature of the processes.

The use or lack of walkplates or walkovers can result in falls around conveyors. In certain companies, interviews revealed that workers didn't use the available walkplates often because of inconvenience. If walkplates weren't available in certain areas, workers would walk across the conveyor itself in order to get to the other side. Sometimes this was necessary due to time pressure. It was also pointed out by workers that some walkplates were very narrow in width, requiring a balancing act to cross them. This in itself could result in a fall onto the conveyor.

Bumped Into

Hazards related to bumping into the conveyor can occur when workers are working at or climbing around the conveyor. This can be in relation to the ordinary job tasks or because of some variance or unplanned event. This is particularly the case if there is a speedup or some emergency that needs to be taken care of immediately. The layout of the conveyor may also contribute to "bumping into" hazards. Sharp corners, appendages that stick out from the conveyor and crowded work conditions may all be involved in this type of hazard. Obstructed aisles and work surfaces are another factor that may result in a hazard to the worker who must contend with extraneous material while still attending to his job functions at the conveyor.

Table 6-9. Data collected from worker interviews--Caught in conveyor hazards.

Hazards Present in the Workplace which the Worker has Minimal Control Over

Hazard Category	
Guarding Problems Total 18	-unguarded slack in chain--catch belt buckle -pinch points difficult to guard -maintenance--must remove guards to fix conveyer -paper cutters partially exposed (unguarded) -fingers could get caught @ roller-belt junction -could put hand past guard -could get fingers caught under dividers attached to conveyor belt -no guard in area of packer (where cans go into the cardboard trays) where operator stands -pinch points between main chain driven pusher bar in machine and shrink wrap feed the rollers -palletizer machine--pinch point between pusher bar and apron that holds cases until full layer is formed -nip points not guarded -could get hand caught in moving conveyor belt while removing trays -squirrel cage behind station could cause a caught-in -can get hand caught underneath belt and roller, removing sheet or cardboard -taking material off belts, get caught between them -could get fingers caught in dough chute -pinch points underneath conveyor table--cleaning belt and roller -placing dough into idler press--catch hands between roller and belt conveyor
Inadequate Maintenance Total 2	-loaf molder--end guard is broken -getting hand caught in conveyor--removing sweet roll from between bent slats
Inadequate Location of Controls Total 6	-can't easily reach shut-off -lock-out switch located in front of workers @ head height, not easily accessible -"stop" button out of reach if worker caught finger or hand in conveyor -controls are located on the other side of conveyor, couldn't stop it in an emergency -no automatic shut-off switch if something is caught between rollers -no shut-off switch nearby on most lines
Workplace Design Total 2	-in order to unload boxes from conveyor, must walk across scrap pile that has accumulated on floor--could slip on scrap pile--get caught in moving conveyor -sometimes have to walk on feed conveyor to clear out loose cans, broken packs, etc.

(continued)

Hazards Related to Pre-Task Operations

Hazard Category	
Workplace Design Total 3	-scrap accumulates on floor from partition slitter -worker stands on stoop (is short)--may lose balance, fall into line -slippery floors and platform
Apparel and Appendages Total 3	-wearing loose clothing--can be dragged into conveyor -could catch glove on canvas belt -sleeves (hands) may catch onto fast moving cans--pull them into seamer
Irregular Material or Conveyor Part Total 3	-shrink wrap sheets don't seal -warped boxes--jam partition slitter -bent slats on conveyor
Shutting Off Conveyor Prior to Working on Conveyor Total 2	-shut off conveyor first, before clearing out loose cans, broken packs, etc. -not shutting conveyor off before unjamming

Hazards Related to Task-Specific Functions

Feeding Something onto Conveyor Total 5	-running short boxes into machine--fingers come close to getting caught in feed roller -running long boxes, operator is too far away from shut-off button to reach it -lying down pushing 12-pak--shoulder holding back rest of cases--really shoves into pusher bar -reaching into machine to thread sheet, get caught in pusher bar or if co-worker started up machine -placing dough into idler press--catch hands between roller/belt
Removing Item from Conveyor Total 6	-removing pans from conveyor -taking material off belts -(sleeves, fingers) may catch onto fast moving cans--pull them into entrance to seamer -removing trays from conveyor belt (catch hand in belt) -removing sheet of cardboard -unloading boxes from conveyor, walk across scrap
Unjamming Total 7	-unjamming conveyor without shutting it off -unjamming conveyor -removing sweet roll from between bent slats -unjamming pallets on depalletizer

(continued)

	-unjamming boxes and cartons on packer machine -unjamming boxes and cartons on packer machine--cartons not scored right -unjamming warped boxes from partition slitter
Cleaning, Mainten-ancing Coveyor Total 2	-cleaning belt and roller--pinch point underneath conveyor -maintenancing conveyor--must remove guards to fix
Workplace Design Total 2	-pile on floor--could slip and fall into conveyor -crawling under/around conveyor

Table 6-10. Data collected from worker interviews--Falling hazards.

Hazards Present in the Workplace which the Worker has Minimal Control Over	
Handling Total 1	-heavy stationary loads--(pushing)
Oil leaks Total 1	-leaks from hydraulic system on conveyor
Work Surface Total 2	-station set near dough mixing area -aren't enough walk places
Hazards Related to Pre-Task Operations	
Oil Leaks Total 1	-oil around conveyor--slip
Work Surface Total 2	-not using walkplaces -slippery waxed floors
Handling Materials Total 1	-cardboard jams on conveyor system
Walking/ Standing on Conveyor Total 3	-standing on conveyor's rollers to push load -walking on rollers to unjam conveyor -walking over conveyor rollers--speed stress or laziness

Table 6-11. Data collected from worker interviews--Bumped into conveyor accidents.

<u>Hazards Present In the Workplace Which the Worker has Minimal Control Over</u>

Climbing Around Conveyors <u>Total 3</u>	-worker sometimes crawls under waist-high conveyor -climbs under conveyor to get to other area of work station -climbing under conveyor periodically--hit head and neck
Objects Falling from Conveyor <u>Total 2</u>	-pans may fall off of conveyor onto worker -electric eyes eliminate problem of objects falling off conveyors
Hitting Part of Conveyor <u>Total 3</u>	-sharp corners on edge of equipment--bruise legs when walking around -pole sticks out at end of machine--can bump head -hit "fingers" that stick up on machine

<u>Hazards Related to Pre-Operation Tasks</u>

Hitting Part of Conveyor <u>Total 2</u>	-slippery floors and platform -runs into corners of machines in workplace if in hurry--boxes on floor
Objects Falling from Conveyor <u>Total 2</u>	-when machine that glues end flaps (packer) on cases of loose pack doesn't work, full cans drop off line, gets knee deep in cans -bumping into each other--co-workers run through station to clear jam -pans may fall off of conveyor onto worker

<u>Hazards Related to Task-Specific Functions</u>

Climbing Around Conveyor <u>Total 3</u>	-worker sometimes crawls under waist-high conveyor -climbs under conveyor to get to the other area of work station -climbing under conveyor periodically--hit head and back
Hitting Part of Conveyor <u>Total 3</u>	-unjamming, can hit forehead -working around conveyors can bump shins, bruise leg on sharp edges -runs into corners of machines in workplace if in hurry--boxes on floor

Table 6-12. Data collected from worker interviews--Overexertion hazards.

Hazards Present in the Workplace which Worker has Minimal Control Over

Height of Conveyor or Workplace Total 7	-platform worker stands on is not correctly chosen -height of conveyor a problem -workplace is low -height of worktable is low -low rollers on conveyor -conveyors aren't lined up -low conveyor
Maintenance Total 3	-roller is missing on conveyor (gravity) -maintenancing heavy motor ladders to repair overhead conveyors, layout poor--need -guide next to the boxes that feeds the conveyor is broken off
Lifting Heavy Materials Total 2	-no mechanized lift for feeding the stacks of board into the press -stacks of boxes coming off the machines are heavy to lift and stack

Hazards Related to Pre-Operation Tasks

Height of Workplace Total 1	-height of platform worker stands on not correctly chosen
Material Stacked Too High Total 3	-boards sometimes get stacked on yellow walkplates--difficult to get load over -stacks of board come in high stacks from feed conveyor -stack sometimes stacked too high

Hazards Related to Task-Specific Functions

Lifting Total 5	-unloading stacks of board from high stacks--must be tilted in order to unload -lifting boxes of doughnut cartons -standing/performing tasks on platform that's at bad height -bringing down heavy motor from overhead conveyor to repair -lifting 40# boxes of topping
Pushing Load on Conveyor Total 5	-hard to push load -pushing load -feeding boards through paper press -pushing materials over yellow walkplates -pushing load against grain of conveyor -pushing load on conveyor--roller missing
Height of Workplace Total 3	-bending over low conveyor -bending/twisting--height of conveyor bad -back strain--(low workplace)

(continued)

Bending Total 2	-feeding stacks of board into press--much bending, twisting, turning -feed board through press--bending constantly 10-15 minutes

Table 6-13. Data collected from worker interviews--Miscellaneous hazards.

OTHER

Hazards Present in the Workplace Which the Worker Has Minimal Control Over

-machine not wired or grounded properly--worker receives electrical shock when he touches metal strip on outside wall of building and metal parts of machine
-pans coming off conveyor can stack onto each other--can cut hands on pans when lifting them off conveyor
-getting burned on bread pans as they're moving on conveyor
-operator of slitter machine could be pinned between conveyor and slitter if forklift operator bumps into conveyor when delivering load
-loads unstable on conveyors--held up by a wooden peg--product and/or conveyor could fall on worker
-machines and forklifts leak oil on floor--slippery, glasses get bumped, knocked off, bands can break--hit face
-transfer conveyor cart has no horn or warning device, can't warn pedestrian or lift trucks in the conveyor path
-when cleaning under the stacking conveyor (must be raised), hydraulic pressure of the lift mechanism holds it up--without a backup system, a hydraulic pressure failure could cause the table to fall

Total 10 -burn by hot glue
-noise affects concentration

Hazards Related to Pre-Task Operations

-machine not wired or grounded properly, worker receives electrical shock when he touches metal strip on outside wall of building and metal parts of machine
-have to hold boxes so they feed in straight, get cuts, callouses on hand
-when piles of boxes get high, operator can't see and boxes hit helper's face
-when cleaning under stacking conveyor (must be raised), hydraulic pressure of the lift mechanism holds it up--without a backup system a hydraulic pressure failure could cause table to fall
-sometimes walks across conveyors just out of laziness--first makes sure it's clear

Total 7 -oil from forklift
-cut fingers on sharp lips of cans that worker picks from area before cans enter single lane convey

Hazards Related to Task-Specific Functions

-machine not wired or grounded properly--worker receives electrical shock when he touches metal strip on outside wall of building and metal parts of machine

(continued)

- -pans coming off conveyor can stack onto each other--can cut hands on pans when lifting them off conveyor
- -getting burns on bread pans as they're moving on conveyor
- -have to hold boxes so they feed in straight, get <u>cuts</u>, callouses on hand
- -operator of slitter machine could be pinned between conveyor and slitter if forklift operator bumps into the conveyor when delivering a load
- -loads unstable on conveyors held up by a wooden peg--product and/or conveyor could fall on worker
- -when piles of boxes get high, operator can't see and boxes hit helper's face
- -machines and forklifts leak oil on floor--slippery, glasses get bumped, knocked off, bands can break--hit face
- -hands get sore from bundling
- -when cleaning under stacking conveyor (must be raised), hydraulic pressure of the lift mechanism holds it up--without a backup system, a hydraulic pressure failure could cause the table to fall
- -paper cuts
- -sometimes walks across conveyors just out of laziness--makes sure it's clear first
- -can bump head on heater bar when replacing plastic wrap roll

<u>Total 15</u>

- -cut fingers on sharp lips of cans that worker picks from area before cans enter single lane convey
- -while unjamming depalletizer, structures drop on fingers or head, causing bruises

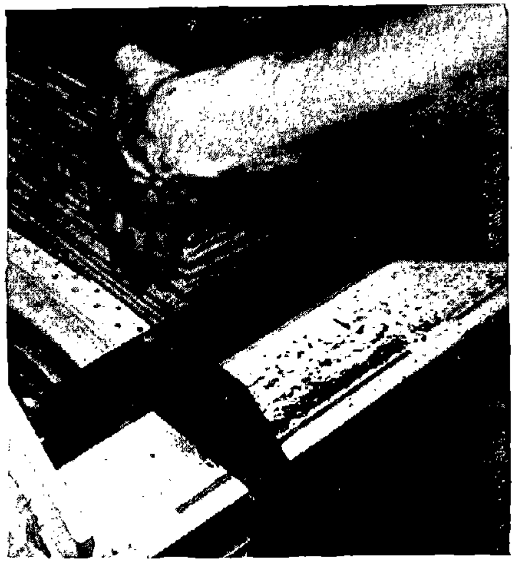
<u>Job Stress</u>

- -heat from press motor close to the feeder station makes the feeder's work station hot--could increase air circulation--feeder gets very hot, especially in summer

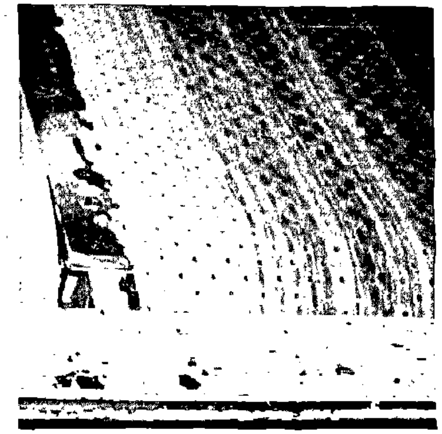
<u>Total 3</u>

- -when production is high, loads pile up at the bander--puts a stress on the operator
- -when production is high, loads pile up at the bander--puts a stress on the operator

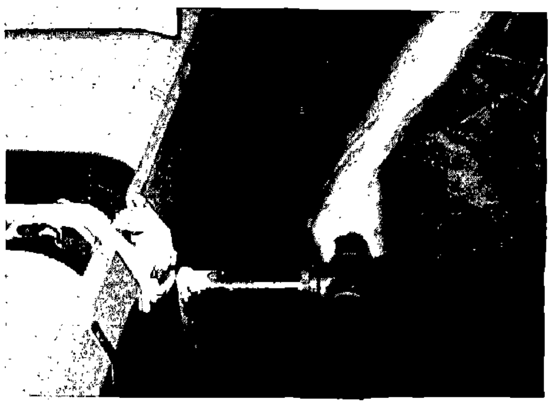
Examples of Human Factors Aspects of Conveyors



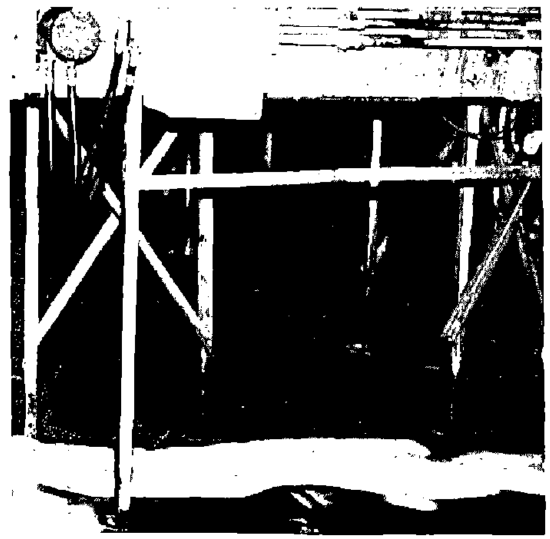
REMOVING ITEMS FROM CONVEYOR - CAN BE CAUGHT IN BELT AND ROLLER



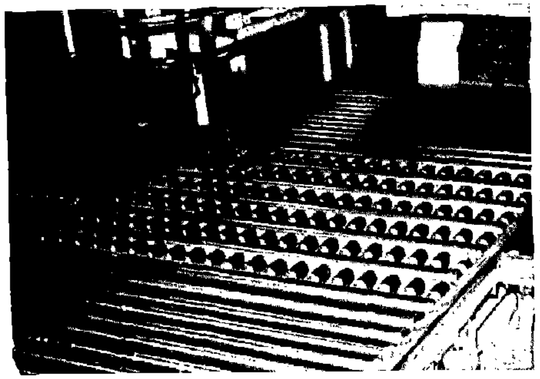
A HAZARDOUS BELT: FRAYED AND MISALIGNED



BROKEN GUARD ON CONVEYOR - MAY CONTRIBUTE TO CAUGHT IN ACCIDENTS



SLIPPERY FLOORS ARE A CONTRIBUTING FACTOR IN STRIKING OR BEING CAUGHT-IN CONVEYORS



TWO-WAY ROLLERS FACILITATE

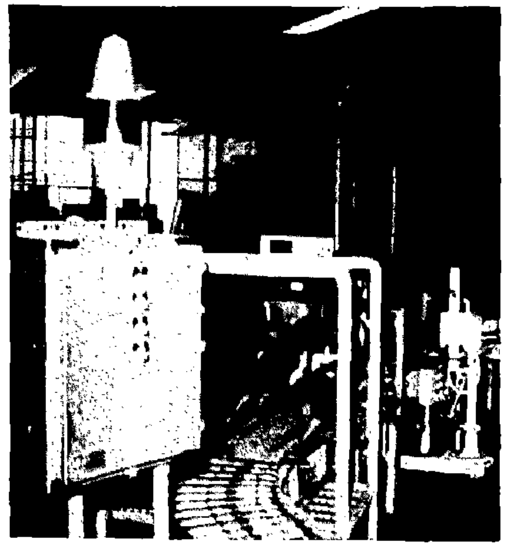
THE MOVING OF MATERIALS ON THE CONVEYOR

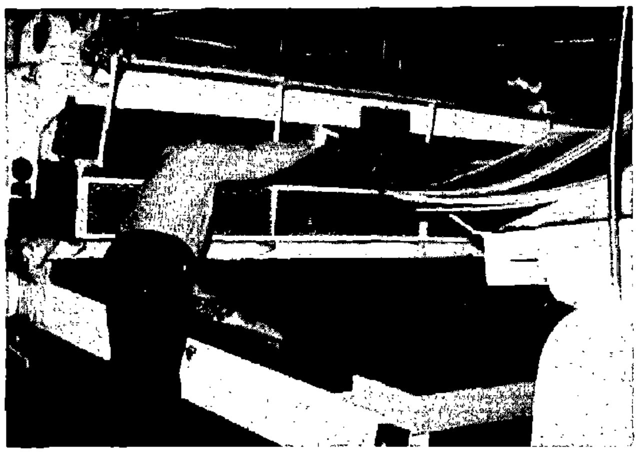
WARNING LIGHT ON

CONVEYOR SYSTEM INDICATES

WHEN A PROBLEM OR JAM-UP

OCCURS ALONG THE CONVEYOR LINE





POOR WORKPLACE AND JOB DESIGN RESULTS IN BENDING

AND REACHING TO PERFORM JOB TASKS - AWKWARD

BODY POSITION CAN RESULT IN OVEREXERTION

AND EXCESSIVE STRESS ON THE WORKER

INADEQUATE HEIGHT OF CONVEYOR RESULTS IN USE OF MAKESHIFT PLATFORM-

STANDING ON A POORLY DESIGNED PLATFORM CAN RESULT IN

UNNECESSARY FATIGUE OR FALLS

Design

The design of conveyor systems has been implicated as a contributory factor both in the accident data that was analyzed and the personal interviews which were conducted with workers.

These design considerations are primarily fixed (as decided by management) or remote factors that are already existing in the workplace and which the worker has to compensate for prior to, or while, they are performing their specific job functions.

Certain of these design factors may be primarily physical in nature such as the presence or absence of machine guarding, location of emergency stops and controls, height of the conveyor and work station, the layout of the conveyor system throughout the plant, and the size of the item being conveyed. Design features, however, may also be related to operational procedures for conveyors, for example, the speed and rate at which an item is being conveyed, and the design of the job being performed at the conveyor, e.g. loading, unloading items, assembly line work, inspection or guidance of the material being conveyed and the relative attentiveness required for each of these job functions.

Training

Most of the workers interviewed reported that training for conveyor operations was virtually nonexistent. Since conveyor systems are highly automated, conveyor operations are considered to require rather low skill. To a large extent, individuals who work in these operations are required to take something off of the conveyor, put something on the conveyor or perform somewhat of an inspection duty by watching the product or material being conveyed to make sure everything is running smoothly. On-the-job training is primarily utilized with an experienced worker present to point out hazards and offer advice. However, in other instances an employe is told what to do and then is expected to do it. In either case, little formal instruction is provided. In some plants, unlike supervisors, laborers receive no safety training.

It was found that many accidents occur to new employes who have been on the job for only a day or in some cases only a few hours. Employes who have been switched from their normal operations to another conveyor were also involved in a number of accidents (job transfer without training). This suggests that some formal training may be valuable since inexperience seems to be an accident factor when performing normal operations as well as while performing irregular functions (i.e., unjamming, unscheduled maintenance). Conveyor operator training too often neglects the unusual or irregular occurrences.

Post-task and Overall Support

All of the hazards mentioned by workers that occurred either "post-task" or as part of an overall support system, concerned maintenance. All of the comments relating to "post-task" hazards concerned cleaning up work areas or machines and reporting maintenance problems. "Overall support functions" comments referred to maintenance schedules, maintenance programs, problem reporting systems, and safety programs. Specific comments concerned the amount of red tape involved in reporting hazards or the foreman's subjective judgment in assigning priorities to maintenance work.

Workers pointed out the following factors that should be considered in conveyor systems; a preventive maintenance program where periodic (e.g. daily) inspections of oil, guards, wiring, points of wear and prompt cleanup and housekeeping staff; define responsibility for task; maintenance programs which quickly respond to worker input concerning problems and feedback to the worker concerning the conditions of their machine; communication system regarding lock-out systems; warnings on broken or maladjusted machines, mechanisms for worker input into the design and safety features of the workplace; maintenance personnel available and accessible; availability of alternative lines; and only trained personnel should perform maintenance operations.

SUMMARY

The data obtained from workers during the site visit phase of the study correlate well with the first three data sources. Hazards that could result in being caught in the conveyor were by far the most frequently cited by workers. Of these, the most important (and frequent) factor appeared to be guarding problems. Similarly, the poor location of start-stop controls (possibly explaining why, in part, the worker fails to shut the conveyor off) was the second most important factor indicated by workers. Finally, hazards concerning housekeeping and workplace design as well as apparel problems were mentioned as other factors leading to caught-in.

Worker reported hazards that implicated being struck by the conveyor or conveyed materials indicated problems with workplace layout (or a worker tendency to take shortcuts and climb around the conveyor) in relation to the conveyor itself. In addition, conveyor design which could result in materials falling off of the conveyor and striking someone was cited.

Hazards related to falls consisted primarily of work surface problems (e.g. oil leaks) and workers standing on the conveyor (rollers) to maneuver loads or unjam them.

Hazards implying overexertion types of accidents were concerned primarily with the height of the conveyor in relation to the work station and the weight of the materials being pushed or lifted.

Hazards collected through worker interviews closely parallel the conveyor accident statistics (i.e. most of the hazards related to caught-in, struck-by and overexertion).

The conveyor should be thought of as a socio-technical system that involves the workers' behavior interacting with the machine. Traditionally the worker has had no control over the technical aspect of conveyors; the layout or design of the workplace and equipment. Similarly, they have had little input into job design and training. Worker input would seem to be a useful source of information regarding conveyor system design and utilization. Since personnel who work at or around conveyors often are not considered to be "skilled" operators, the only training they receive is brief, on-the-job training. They usually receive no training for unusual or irregular aspects of the jobs or variances such as unjamming, speedups, unscheduled maintenance, unexpected starts, varying material, varying job tasks, etc. Conveyor accidents often result from these unprogrammed events. Many variances can be controlled by behavioral standards that address factors such as disengaging or bypassing guards, untrained personnel aspects of maintaining or repairing conveyors or lock-out procedures. Therefore, a safe conveyor system should include physical factors such as guarding as well as be complemented by behavioral-social factors.

RECOMMENDATIONS

In order to design the "ideal" conveyor system, one must consider socio-technical factors. The technical factors are those involving equipment and workplace design. Social and psychological factors include job design such as proximity to other workers, potential for interaction, control over pace, speed stress, need for attention. Traditionally, only management has had control over these factors. Thus, they are fixed or "predetermined" before the worker enters the workplace. At the predesign stage, worker input regarding the following factors should be considered.

Workplace--

-Location and layout of conveyors
  Shouldn't require long reach or repeated, uncomfortable positions to place or remove materials
  Place stairs or walkways (nonslip) where needed to get around conveyor
-Adequate lighting, important for maintenance work, unjamming
-Floors, nonslip, grid
-Noise reduction: to prevent stress, relieve monotony, allow communication between workers, particularly in emergencies

Equipment--

-Guard pinch points
-Controls in proximity to workers--for jam-ups, caught-in accidents
-Trays under conveyor to catch water or drippings
-Height of conveyor--to prevent bending
-Side railings--to prevent falling objects
-Smooth edges on conveyor guides, rails, etc.
-Feasibility of shut-off switch or line along length of conveyor
-Feasibility of using rubber band powered roller conveyor (prevents caught-in accidents)
-Perform stress test if conveyor hangs from ceiling

-One continuous guard instead of separate sections
-Availability of alternative lines or in-line storage areas to reduce speed stress when a jam occurs
-Warnings before conveyor starts up
-Warning lights--visual feedback
-Audio feedback--horns
-Design conveyors for in-line "storage" so sections of processing may be easily shutdown and unjammed without affecting the production on other part of the line

Job--

-Proximity to other workers
-Potential for social interaction
-Control over pace, speed stress, preventing shortcuts
-Fixed work station, monotony, level of attention necessary
-Job tasks; reduce bending, twisting, reaching, etc. Standing all day
-Buddy system--to avoid turning on conveyor when another is working on it

General Support--

-Preventive maintenance program; daily, weekly, etc.
-Safety training and safe procedures; lock-out, cleaning, unjamming, lifting, back exercise program, lifting standards, housekeeping, keeping guards in place, etc.
-Clothing; not loose, well fitted gloves, nonslip shoe soles
-Communication; management response to worker input, feedback to workers
-Good housekeeping system; eliminate clutter that could cause a worker to bump into conveyor

After the system is designed and installed, the worker element enters the system and as tasks are initiated, the human interaction with the machine must be considered. Pre-task functions such as setting up or preparing for actual conveyor operations required the interaction of behavior with equipment. Therefore, both the worker and management have the potential to control against hazards. The following factors are important to consider in the pre-task phase of conveyor operations.

-Preventive maintenance program
-Training--for regular and unusual situations, including shutting off before unjamming, not wearing loose clothing, etc.
-Setting up work station--lifting, height of platform adjusted correctly

Similarly, during the task itself, the worker is interacting with the machine and therefore has potential for control. At this phase the following factors are important:

-Worker skills, training, experience
-Alertness
-Communication and interaction
-Housekeeping

Overall support functions such as maintenance, communication network, safety program, training, etc., are also worker-management controlled systems.

Since it can be seen that the worker is a major part of all task systems, their input in workplace design would seem logical. The ideal system is not only designed to eliminate mechanical hazards (pinch points, sharp edges, etc.) but designed with the worker in mind in all phases of the conveyor system. In this way, behavior or human factors that are involved in accidents can be considered and controlled before an accident can occur.

In every phase of design of management of work, the interaction of socio-technical factors should be considered.

Recommendations for Future Research

The following recommendations for research or program development NIOSH may wish to consider or initiate in the future.

- Provide research and technical support for developing conveyor related standards emphasizing behavioral requirements for those dealing with conveyors.

- Initiate experimentation utilizing worker input in design of conveyor systems: equipment, layout, job, pace.

- Develop checklists of design and safety features for equipment designers and management.

- Examine social interaction effects of assembly line operations--include factors such as geographical isolation, noise, machine pacing.

- Initiate experimentation with job design and workplace layout of conveyor operations to eliminate bending, reaching, twisting, etc.

- Develop training programs for conveyor operators (including all workers temporarily rotated into conveyor jobs) and maintenance operations emphasizing preparation for variance events or coping with unusual events.

- Experimentation with reduction of stress: examine factors such as speed stress, degree of worker control over operation or pace.

REFERENCES

American National Standards No. B20.1-1972 Safety Standards for Conveyors and Related Equipment, American Society of Mechanical Engineers, New York, New York.

American National Standards No. B20.1--R1976, Safety Standards for Conveyors and Related Equipment, American Society of Mechanical Engineers, New York, New York.

Cherns, Albert B., Can behavioral science help design organizations? Organizational Dynamics, Spring, 1977, pp. 44-64.

Colligan, M. J. and Smith, M. J., Proceedings of the American Psychology Association, Consulting Psychology Section, "Evaluating Industrial Psychogenic Contagion Reactions". 1977

Davis, Louis E. and Taylor, James C., Design of Jobs, Penguin Books, Ltd., Harmondsworth, Middlesex, England, pp. 167-168, 419 1972.

Mann, Floyd C. and Hoffman, Richard L., Automation and the Worker: a study of social change in power plants, Henry Holt and Company, Inc., New York, New York.

Miller, James G., Adjusting to overloads of information, Disorders of Communication, Williams and Wilkins, Baltimore, 1964.

National Safety News, "The Versatile Conveyor--A Type for Every Job," February 1977.

OSHA Safety and Health Standards (29 CFR 1910) (Revised January 1976) U. S. Department of Labor Occupational Safety and Health Administration.

CHAPTER 7. GENERAL CONCLUSIONS AND RECOMMENDATIONS

This chapter presents findings in several areas common to the types of equipment studied, which are appropriate for general discussion. The recommendations included here are also of a general nature and are applicable to materials handling in industry as a whole.

Topics to be discussed include: (1) the systems status of conveyor, crane and industrial truck hazards; (2) human factors deficiencies in management practices; (3) current practices among the plants visited which demonstrate distinctive features of hazard management for these equipment types; and (4) general recommendations regarding the improvement of behavioral hazard management of material handling operations.

THE SYSTEMS STATUS OF MATERIAL HANDLING EQUIPMENT HAZARDS.

As outlined in Chapter 2, hazards can be generalized to include any event, condition, or behavior which occurs in the sequence starting with equipment design and ending in the performance of a task, and which affects or influences the safety of that task. The data of the last three chapters bears out this assumption, showing that the hazards discussed typically distribute themselves into these categories:

(1) physical hazards, related to design, malfunction or breakage of equipment, accessories, and objects in the workplace;

(2) operational hazards, arising from the uses and applications of equipment in particular situations, and from mis-applications and the combined use of two or more items not necessarily designed to be used together;

(3) hazards arising from the negligence of workers, supervisors, managers, technical or engineering staffs, and executives, in failing to exercise sufficient attention and responsibility in anticipating and preventing either physical or operational hazards.

In the events preceding an injury, all of the above may be relevant. But attention to one type, as an over-reliance on the correction of physical hazards, may leave the others unmanaged.

Examples of each kind of hazard are found in Chapters 4, 5, and 6. Physical wear and tear on machine parts typically produces hazardous conditions, and these often present threats to anyone in the vicinity. Operational hazards, on the other hand, are more numerous but also more specific to a worker or a work situation. Individual tasks and different ways of performing the same task dictate this variation. Yet these hazards have enough common features to ensure that they are reliable and valid indicators of problem areas.

Where the hazards of damaged hoist cables, unguarded nip points, or worn-out truck brakes represent negligence in the areas of maintenance or hazard reporting, operational hazards arise more often from misapplication of equipment, or combinations of unknown factors. Operational hazards can be expected in a system from which most of the obvious unsafe conditions and design problems, as well as negligence, have been removed. In a glass bottle factory, a worker stacked cartons of bottles up to 8 feet high on a pallet after removing them from a conveyor, and commented on the dangers of injuring his back while stacking. Lack of communication was the central problem - it was the buyer's decision, not plant management's, to require 8-foot stacks on pallets. Simply noting this doesn't condone the practice, but it recognizes a sharing of responsibility in abating the hazard.

As with the unsafe act notion, negligence is often blamed for accidents which involve more factors than can be easily detected and studied. Yet negligence itself, as conduct below some standard of care, is a relative notion, depending on intentions and past practices. One result of over-reliance on OSHA standards, a widespread practice, is that total compliance with the regulations can be achieved, and yet accidents and injuries continue to occur. Many employers visited have centered their safety efforts around compliance with OSHA regulations, but few of them demonstrated programs aimed at detecting unknown hazards, or conditions, behaviors and practices leading to hazards. Even if negligence is more likely to be found, diligent searching for hazards and greater attention to the large area of operational factors is called for. These hazards will otherwise persist if reliance on specification and physically-oriented regulations alone continues.

A second systems assumption supported by the data was that many hazards depend on interactions between lifting devices and accessories, between cranes and fork-lift trucks, and between the lifting device and the particular products and materials being lifted. Since these interactions often involve different plant functions, they are often controllable only through management and technical efforts.

No uniform or consistent patterns can be used to predict such hazards, since diversity of occurrences and conditions make every operation somewhat different. In the usual lifting tasks of cranes and industrial trucks, such variations are the major source of hazards. Diversity exists also in the operators of many of these machines who often have other primary jobs and do lifting tasks only incidentally. In such applications, it is not surprising that training and certification standards would have little meaning.

HUMAN FACTORS DEFICIENCIES IN MANAGEMENT PRACTICES

The design-to-operation process undergone by a typical lifting device has been understood by system safety specialists using fault-tree analysis, the Management Oversight and Risk Tree (MORT) system (Johnson, 1975), and other sophisticated analytical techniques. Of the plants visited on this project, none used such techniques for routine material handling safety, and many revealed practices that took no account of the impact on safety of economic and purchasing decisions.

Competition, sales practices, economic pressures and traditional engineering orientations were found to be major limitations to human factors approaches to safety and health. What innovations have occurred seem chiefly to lie in the areas of improved electronic control of cranes, hoists, and conveyor on-off systems. Yet some, such as crane load moment indicators, are treated skeptically by major manufacturers and operating engineers who prefer to rely on their own skilled judgements, especially in emergencies.

Economic considerations are paramount in decisions to stay with old equipment, as was evident in almost every plant visited. Except for manufacturers, most users had some industrial trucks of World War II vintage; and they appear to struggle in an uphill battle to balance maintenance and cost-effectiveness against safety.

Other economic factors are barriers to industry-wide acceptance of hazard management. Manufacturers and dealers hesitate to publicize crane and truck hazards in order to limit product liability, and out of the belief that competition will outsell them if they request or insist that the user adopt hazard management techniques.

A serious shortcoming, also noticed in the majority of plants visited, was found in concepts of training material handling equipment operators. While practices varied widely, mobile and overhead crane operators received the most preparation and training, with industrial truck operators next, and conveyor-workers received little if any training. A common limitation observed was that safe equipment use training was not integrated with other plant and operations training. But a more serious one reflects the management belief that when training is done, responsibility for safety rests with the employee.

The complexity of these issues is indicated by accident records, expansion of crane and hoist use, and the apparent improvement of the control characteristics of cranes and hoists. A practical systems analysis of some of these interacting factors suggest that training operators in the obvious maneuvers of lifting set loads, adjusting boom cranes for various load movements does not incorporate the critical aspects of unexpected hazards in lifting. Similarly, teaching a fork-lift operator the necessary maneuvers for turning, backing, inching, and so on may not prepare him or her for the novel, hidden, or unknown sources of variance in the truck, roadway, load characteristics, or accessories that need to be handled.

The traditional handling tasks must be a part of training. But equally important is the necessity to give operators some experience in the potentially hazardous nature of poor hitches, poor maintenance of hoists and accessories, failure of communication between operators and hitchers, excessive loads, and speed stresses. Industrial truck operators need practice in quick but safe stopping for the unexpected pedestrian, or in leaping safely from a tipping truck or avoiding falling loads. In short, a large section of the training should not be in simply knowing about the sources of hazards with the equipment, but in actually experiencing under controlled training conditions the effects of these operational hazards upon the ability to carry out effective operations.

A third deficiency concerned the maintenance of conveyors, cranes, hoists, and industrial trucks. A wide range of practices were again seen in this area, with workers in some plants praising the mechanics and in others, unskilled workers attemtping to fix defects themselves rather than delay work for a trip to the repair shop.

One factor explaining the differences is the business itself - the nature of the product. In those firms where metal fabricating, foundry work, machine tooling, assembly, engine construction, or manufacturing of the material handling equipment itself, was done, maintenance was not a major safety problem. In these plants, the work of maintenance is similar to the work of production, and the skills are the same. It was in the bakeries and warehouses where few workers could substitute for skilled engine or equipment mantenance, that the division of labor results in hazards from poor maintenance.

DISTINCTIVE HAZARD MANAGEMENT EFFORTS IN PARTICULAR SETTINGS.

As anticipated, manufacturers of the equipment studied had evolved a number of innovative techniques for materials handling safety. In two of the country's largest crane and hoist manufacturing plants, specific positive programs had been established in controlling hitching and lifting hazards by developing technical specialists in sling, chain and attachment use, and hitchers and hitching teams specializing in difficult lifts with all types of cranes and hoists. The sling and chain specialist in one plant, a man of some 20 years experience, maintains all crane-related inspection records, and conducts training courses for crane operators and floor men. From his small shop where slings and chains are stored, he acts as a chain-maker, a maintenance man for worn or damaged accessories, a consultant for the proper selection of attachments in unusual lifts, and a creator of novel riggings and lifting aids for unique or special jobs. In keeping with several assumptions made earlier, this person demonstrated that skill and experience in the particulars of lifting with cranes can have a greater impact on safety than the safety department personnel trained in more traditional, but more general, approaches.

This same plant, however, had innovated in precisely this area of traditional safety as well. Although safety as a plant function was lodged within the secutity division, hazard management aides in this division had been trained to supervise, monitor, research, and analyze specific sources of hazards. One had been trained in noise measurement and control and another in behavioral management of the handling of carcinogenic materials. These specialists spent more time on the working floors of the company than was common among other safety departments observed, which helped in making safety more a part of hour-to-hour and day-to-day control of hazards.

A second manufacturer demonstrated even further a commitment to safety in both crane design and operation. Management here estimated that they were 90% of the way toward full compliance with OSHA standards prior to OSHA's existence. Since 1968 they have proof-tested all manufactured cranes. They employ eight full-time specialists who maintain cranes, hoists, and industrial trucks in their own plant; twenty additional field-service maintenance people service their cranes for users in the field, and specialize in both operation and maintenance. Field-service personnel attend sessions at the home plant every three to four months to review problems and ideas with top engineering and safety specialists with long experience in construction and use of cranes and hoists. Proof-test and field-test experience of workers with cranes serve as the basis for job-training of crane operators.

In this company's plant, novel, special, or very heavy lifts are supervised by technical people after extensive planning and operational designing is done. Everyone involved in the task proceeds with superlative caution in monitoring and carrying out the lift, and a rigging foreman is required on every such project to oversee the use and care of slings, chains, and wire ropes.

It is clear that this corporation has effectively integrated moment-to-moment safety management with cranes and hoists, on the one hand, with regular manufacturing and production operations on the other. In moving extensively into the human factors design of controls and cab environments for crane operators, as well as design of crane hooks and slings, they have engineered out of their machines the crude and difficult operational controls characteristic of earlier designs. Improvements in the last decade have made their cranes and hoists far more responsive to human control. Formal procedures serve to integrate the operator and hitcher functions, giving the crane operator primary responsibility in all lifts. Heavy emphasis on preventive maintenance and technical supervision of set-up men completes the picture.

Yet this situation is not without its problems. The management of this firm and others claim little influence over purchasers of their equipment in controlling and managing hazards. What is needed is the formalization of these effective practices into specific guidelines so that users too can reduce material handling accidents.

Hazard Control In User Plants.

A large manufacturer of paper machines demonstrated a wide range of practices incorporating hazard management principles. While worker safety and health are looked after by an energetic and experienced safety director, department and division safety are the responsibility of the heads of these units. Top management's commitment to safety is evident in this plant; the safety department suggests, but only top management gives safety directives. Top executives in this company, which is largely family-owned, frequently tour the plant talking with workers. Several of the executives themselves worked on jobs in the plant as beginners.

Machine parts produced in this plant may exceed several stories in height when partially assembled. So many one-of-a-kind lifts are made in the crane bays of this plant that plant engineers have become accustomed to taking pictures of parts to determine the probable center of gravity. Holes or pegs are then provided for lifting and turning the piece by overhead crane. A rigging supervisor and a specialist responsible for lifting straps and slings often supervise a team of floor-men who do the hitching work.

Hazards are detected and recorded in this plant. They are primarily spotted during inspection tours made by safety department personnel and safety and health interns. They recommend corrections and require action and subsequent notification in writing signed by the person responsible. The only drawback is one continually repeated in this report: hazards are described in terms of unsafe conditions and unsafe acts.

In a metal rolling mill we observed again effective integration of production operations with close supervision and management of crane hazards. Although the plant managers made no sharp distinctions between operational, physical, and worker negligence hazards, they recognized and actualized the need for continuous positive efforts to reduce and control operational hazards. The plant manager is an engineer with considerable technical knowledge of crane and hoist design and operations. He himself had designed improvements in the hydraulic motor controls of vacuum lifting with pendant-controlled cranes to provide a back-up system in case one hydraulic unit failed. He exercised direct technical authority throughout the mill and participated in work design and operations involving all types of crane and hoist hazards, often serving as a consultant to department supervisors.

In a large brewery, automation and the use of computer-controlled conveyors has eliminated some of the hazards to conveyor-related workers, primarily through eliminating the jobs and workers themselves. The tasks remaining in conveyor-using parts of the bottling and packaging process which still require workers involve minimum exposure to in-running nip points or unguarded drive gears. People working at key locations in the conveyor-machine configuration serve to initiate change, as when the package needs of the product change.

Automation in warehousing, including automated storage and retrieval systems, enjoy the same benefits. Some are operated by one person, some only by computer cards. Most eliminate the hazards of individually-operated high-reach order-picker trucks.

By and large, however, this direction toward automation can be taken only by businesses running highly routine, mass-production operations; in these processes, the variances have been removed and the situation is ripe for introducing machine control. But where variance still rules, as in many industrial truck and crane applications, human adaptability, flexibility and skill are the only feasible answers.

One final example of the impact of personnel and compensation practices on safety was observed in a plant engaged in glass bottle manufacturing. Standards of performance are defined for management personnel which include areas such as safety, housekeeping, below-average accident rates and accident prevention. Periodic reviews by plant management determine whether a supervisor or manager fails to meet, meets, or exceeds these standard levels of performance. Merit raises, or portions of them, are then based on these ratings.

GENERAL RECOMMENDATIONS

In this chapter has been presented an overview of some of the practices encountered during the site visits. Some problems are the immediate symptoms of poor practices in controlling safety hazards in materials handling. Others are examples of exceptional practices and measures adopted by individual firms which supported the notions and assumptions of hazard management presented in Chapter 2.

In this section, a number of general recommendations are made which are not specific to a particular equipment type, but which are supported by the total evidence presented in Chapters 4, 5, and 6. Rather than impractical or untested suggestions, these recommendations urge a wider dissemination and adoption of existing practices which have already reduced material handling injuries among their proponents.

1. <u>Integration of Industrial, Governmental, and Worker Resources for Improved Safety and Health in Material Handling.</u> Efforts to improve crane, industrial truck, and conveyor safety and health, on the part of manufacturers, dealers,

equipment users, labor unions, and State and Federal governments, need to be integrated for the more effective sharing and wider adoption of specific, proven measures and practices of hazard control and management. Such programs as joint industry-government conferences and workshops which bring together manufacturers, dealers, users and regulatory personnel can contribute greatly to this need. Promoting communication between such groups can begin to manage the relationships between them, including more efficient use of resources.

2. Performance Standards for Preventive Hazard Management Are Needed to Complement OSHA Regulatory Standards. The roles of government regulatory standards and of industry-promulgated voluntary standards need to be thought through. While giving maximum protection to the worker threatened with injury or illness, Federal regulatory policy makers can promote and strengthen the entire area of positive, preventive measures and practices in the design and operation of materials handling equipment. Distinctions need to be made between positive, specific standards of preventive safety behavior and performance, which are largely not subject to inspection, and precisely defined regulatory requirements which will stand up in court.

3. Federal Support and Initial Funding for a Materials Handling Safety and Health Research Institute. Such an institute is needed to promote and subsidize research in the human factors of designing, operating, and controlling the hazards of industrial trucks, cranes, hoists, and conveyors. Research issues include the improvement of control characteristics for these machines, development of improved methods of communication among members of work teams, and development of research designs for evaluating safety factors between different configurations of equipment and material.

4. NIOSH Research in the Human Factors and Systems Management of Hazards in Materials Handling. The results of this report present a wide range of research questions appropriate for NIOSH, the most important of which include:

A. The relationship between hazards, accidents and injuries and the degree to which unexpected, unplanned, and unprogrammed events determine job design.

B. The information, data, and communications needs of conveyor, crane and industrial truck users and workers for the effective, continuous control of operational hazards in materials handling work.

C. The development of workplace instruments for efficiently detecting, tracking, and abating the hazards of these equipment types, as well as scientific techniques for analyzing and assessing the causes and factors of operational, physical and negligence-based hazards and accidents.

5. Hazard Management as the Integration of Safety and Health into the Management of Production and Other Plant Activities. The many key activities and functions of the modern industrial workplace that have impacts on worker safety and health, especially in materials handling, are governed by standards of performance which can be extended to the injury and illness prevention area. As indicated by the comments of workers and managers, material handling safety is influenced by purchasing people in specifying equipment and accessories, by plant engineers in deciding workplace layout, by industrial engineers in deciding features of task and job design, by personnel and safety people in

selecting, training and assigning workers to different tasks and machines, by maintenance people in preventing serious machine failures, and by top management determining an overall organizational climate conducive to effective detecting, reporting and recording of facts related to accidents. Responsibility for safety must permeate each of these functions if their impacts on safety are to be managed.

5. Training and the Management of Worker Skills Needs a Human Factors Emphasis Which Incorporates Systems Control Concepts and the Control of Variance. Training of operators of cranes, industrial trucks, and conveyors, as well as occasional users of these equipment types, needs to be improved to incorporate actual experience in controlling the variances and unexpected hazards arising in materials handling jobs. Management of worker and operator information and communication needs must supplement training. Where traditional training is needed to insure basic operating skills in routine work processes, it cannot and does not incorporate often enough the variable, changing, and unexpected conditions and behaviors which define the hazards of handling heavy materials.