

Appendix C

Independent Oversight Special Study of Hoisting and Rigging Incidents Within the Department of Energy

October 1996

**INDEPENDENT OVERSIGHT SPECIAL
STUDY OF HOISTING AND
RIGGING INCIDENTS WITHIN
THE DEPARTMENT OF ENERGY**



October 1996

**Office of Oversight
Office of Environment, Safety and Health
U.S. Department of Energy
Washington, DC 20585**

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EXECUTIVE SUMMARY

This report presents the results of an analysis of Department of Energy (DOE) hoisting and rigging (H&R) incidents, covering the period beginning October 1, 1993, and ending March 31, 1996. The study, initiated at the request of the Assistant Secretary for Environment, Safety and Health, was performed in response to concerns over the safety of H&R operations, and the perception that accidents were occurring with greater frequency. The purpose of this study was to determine whether additional oversight of H&R operations is warranted. The results of this effort will be combined with information from other independent oversight initiatives, to determine the effectiveness of the Department's overall safety management program, and to develop strategies to combat systemic problems that hinder the attainment of satisfactory safety performance.

Hoisting and rigging includes the raising, moving, and unloading of materials, either by large power-lifting equipment, such as cranes and forklifts, or by smaller, light duty manual and power-operated equipment, such as hoists, chainfalls, and block and tackle. These activities, which pervade work performed throughout the DOE, have long been viewed as an area presenting significant safety challenges.

An H&R incident is defined as an unsafe situation that either 1) required immediate cessation of the activity, 2) resulted in an accident, or 3) almost incurred an accident (i.e., a near miss). In the past five years, H&R incidents have resulted in fatalities, personal injuries, and property damage — accidents. Since October 1993, three out of every four H&R incidents resulted in an accident where personal injury, property damage, or both were incurred. Despite management attention to H&R operations in the aftermath of these events, incidents continued without a pronounced trend. The activities and operations that constitute the DOE H&R process have not basically changed, and management has not been successful in improving the process.

Half of all H&R incidents are associated with the use of crane equipment, and almost a third of all H&R incidents involve forklifts. Seventy-four percent of crane incidents, and 90 percent of forklift incidents, resulted in accidents. Inattention to detail, closely followed by deficiencies in work organization and planning, is the leading cause for crane incidents. Inattention to detail and procedures not used or used incorrectly are responsible for most forklift incidents. Deficient work planning and organization, and inadequate or defective engineering design or configuration contribute to almost half of all incidents involving "other" H&R equipment (i.e., manual and power-operated hoists, chainfalls, and block and tackle).

The strong relationship identified in this review between the root causes of H&R incidents and the type of equipment used provides a tool that can be used to improve H&R safety performance. For example, as the Department transitions from production to environmental restoration, greater use of subcontractor-operated mobile cranes is anticipated. Greater oversight of subcontractor operations by line management that emphasizes the importance of attention to detail and effective work organization and planning will improve the safety of their operations. Implementation of effective strategies to address incidental use of heavy-duty H&R equipment, such as forklifts, will contribute to reducing a large proportion of H&R accidents.

INDEPENDENT OVERSIGHT SPECIAL STUDY OF HOISTING AND RIGGING INCIDENTS WITHIN THE DEPARTMENT OF ENERGY

1.0 INTRODUCTION

The Office of Oversight analyzed hoisting and rigging incidents that occurred within the Department of Energy between October 1993 and March 1996.

This report presents the results of an analysis of Department of Energy (DOE) hoisting and rigging (H&R) incidents during the 30-month period beginning October 1, 1993, and ending March 31, 1996. It is one of numerous independent assessment activities performed by the Office of Oversight. The information presented in this report will be combined with the results of other independent oversight efforts, including site-specific evaluations and special studies of important topical areas, to evaluate the effectiveness of the Department's overall safety management program and identify areas for further evaluation.

BACKGROUND

Hoisting and rigging activities present significant safety considerations.

Hoisting and rigging activities include raising, moving, and unloading materials, either by large power lifting equipment, such as cranes and forklifts, or by light duty manual and power-operated equipment, such as hoists, chainfalls, and block and tackle. These activities are viewed as presenting significant safety considerations. This view is shared not only by the Department, but by other Federal government organizations and private industry. Recent events, observations, and findings from various inspections by the DOE, as well as general perceptions, have heightened the awareness and concern for the safety of H&R operations within the Department. This study was performed in response to these concerns at the request of the Assistant Secretary for Environment, Safety and Health.

Many DOE activities involve technologies, equipment, and processes that are unique to a specific program or facility. However, H&R operations do not vary significantly among the various DOE sites. Depending on the lifting source, load-lifting cables may be used (such as in the case of crane operations) to raise, suspend, and move materials that are generally secured by ropes, chains, or synthetic web straps. H&R tasks pervade work performed throughout the DOE complex in the construction, operation and maintenance, decommissioning and decontamination, and environmental restoration phases of a facility or project. Consequently, a better understanding of safety performance of H&R operations can have wide application.

Hoisting and rigging incidents led to a "lessons learned" workshop in 1994 to improve safety performance.

Large machinery (e.g., cranes), suspended loads, and substantial hazards characterize H&R operations. The safety of H&R tasks is dependent on sufficient supervision, proper hazard

analysis and work planning, and appropriate selection, operation, and maintenance of equipment. Within the past five years, the safety performance of H&R operations has been marred by events that resulted in serious injuries to workers, substantial property damage, and fatalities at the Idaho National Engineering Laboratory in May 1991 and at the Oak Ridge Reservation in November 1992. These events heightened the need for increased management attention to H&R operations.

Recurring incidents indicate that safety in hoisting and rigging requires further improvement.

In April 1994, the Department sponsored the Hoisting and Rigging Lessons Learned Workshop, attended by DOE managers, supervisors, and staff, and contractor personnel. The workshop was devoted entirely to examining the knowledge gained from recent hoisting, rigging, and materials handling incidents for purposes of improving the safety of future operations. However, H&R safety performance continues to be of concern as incidents and accidents recur.

Throughout this report, reference is made to H&R incidents as distinct from accidents. An incident is defined as an unsafe situation that either 1) required immediate cessation of the activity, 2) resulted in an accident, or 3) almost incurred an accident (i.e., a "near miss"). An accident is a situation that results in fatality, personal injury, or property damage. The term "accident" does not include "near misses."

PURPOSE AND OBJECTIVES

Causes and trends were examined to identify actions to improve safety performance.

This analysis was conducted to better understand H&R incidents throughout the DOE complex in order to determine whether additional oversight of H&R operations is warranted. If focused correctly, additional oversight of H&R operations may improve safety performance by uncovering information helpful in combating systemic problems that hinder the effectiveness of safety management throughout the Department. Accordingly, the study is intended to:

- Determine the principal causes of H&R incidents.
- Identify significant trends in H&R incidents and accident consequences.
- Identify potential actions to prevent or limit H&R incidents.

ORGANIZATION OF THE REPORT

The technical approach, including sources of information and analytical techniques used, is provided in Section 2. Section 3 presents the results of the analysis. Conclusions are contained in Section 4. Appendix A contains information on the analytical and statistical methods used. Appendix B lists those involved in developing the report.

2.0 APPROACH

This section describes the method used to examine the safety performance of H&R incidents throughout the Department. It presents information on the data analyzed and techniques employed to address the study objectives.

OVERVIEW OF APPROACH

Incidents reported in the Occurrence Reporting and Processing System were examined.

The DOE Occurrence Reporting and Processing System (ORPS) served as the principal information source for incidents relating to H&R operations. Various analytical techniques, including Pareto analysis, process control, regression analysis, and other statistical methods were applied to information on H&R incidents extracted from occurrence reports to analyze root causes and identify meaningful trends.

ANALYTICAL TECHNIQUE

A narrative search was performed on data contained in ORPS to extract an initial set of 491 occurrence reports, corresponding to the October 1, 1993, to March 31, 1996, period, describing incidents related to H&R¹. An H&R incident was considered relevant for further analysis if it:

- Occurred during hoisting and rigging operations, or the use of hoisting and rigging equipment, as defined in the U.S. Department of Energy Hoisting and Rigging Handbook

AND if it:

- Resulted in unsafe or improper conditions that necessitated the immediate suspension of the hoisting and rigging operation for any period of time, led to a near miss, or caused an accident.

Occurrence reports documenting the identification of suspect or counterfeit parts in H&R equipment were excluded if the part in question did not contribute to an operational incident. Suspect or counterfeit parts were not reported as the root cause for any of the incidents analyzed. Similarly, incidents pertaining to skin, clothing, and equipment contamination during H&R operations were excluded unless they created a contamination incident.

Although information in the Occurrence Reporting and Processing System has some flaws, the hoisting and rigging incidents reported there warrant attention.

Inconsistencies and ambiguities were identified in the assignment of root causes to incidents, as reported into ORPS. For example, it was not clear from ORPS occurrence reports why the root causes of certain incidents were attributed to management or poor work environment while

¹See Appendix A for a description of narrative search technique.

similar incidents were attributed to inattention to detail. This lack of clarity in root cause determination is consistent with deficiencies in occurrence reporting identified by the Office of Oversight in November 1995, when it was reported that some personnel responsible for occurrence reporting are not adequately trained in the analysis of root causes². Because this study used only information readily available from ORPS, no interviews were conducted to resolve these issues. However, these areas are identified as warranting attention to improve the utility of ORPS³. Despite these shortcomings, the number of H&R incidents recorded in ORPS deserves attention, especially because H&R accidents can have severe consequences.

There were 131 relevant hoisting and rigging incidents between October 1993 and March 1996.

Keeping in mind these issues, along with the variability in terminology used to report H&R incidents, application of this technique and the associated criteria produced 131 relevant H&R occurrence reports for the 30-month period. Information contained in these reports on the characteristics of each H&R incident was used to construct the database analyzed. As discussed in Appendix A, this database represents approximately 41 percent of the total number of relevant H&R occurrences contained in ORPS; thus it provides a basis for extrapolating and making inferences to the entire population with less than a five percent error at the 95 percent level of confidence⁴.

3.0 RESULTS

This section summarizes the study results, including types of incidents and root causes and trends.

OVERVIEW OF SAFETY PERFORMANCE

After a fatal accident in November 1992, Departmental hoisting and rigging activities were curtailed.

The November 1992 H&R fatality at the Oak Ridge Reservation K-25 Gaseous Diffusion Plant, along with other less serious incidents at this and other sites, precipitated a suspension of H&R operations at Oak Ridge beginning in April 1993, which lasted approximately three months. Similar curtailments in H&R activities were implemented elsewhere in the Department.

Despite various management actions, incidents continue to recur.

²See report entitled Independent Oversight Special Study of Occurrence Reporting Programs within the Department of Energy, November 1995, p. A-4.

³Root causes analyzed were those assigned to incidents contained in occurrence reports. No adjustments were made to reconcile inconsistencies. Definitions for root causes are defined in DOE Order 5000.3B (1/19/93-10/29/95), and its successor, DOE Order 232.1 (10/30/95-9/25/99, both entitled Occurrence Reporting and Processing of Operations Information.

⁴See Appendix A for inferential strength of sample.

After this period, beginning in January 1994, the number of H&R incidents reported throughout the Department followed a generally downward trend, reaching a low point in June 1994, shortly after the DOE Hoisting and Rigging Lessons Learned Workshop held in April that same year that was designed to improve H&R safety performance. While the Oak Ridge fatality, the subsequent cutback in H&R operations Department-wide, and the DOE workshop may have had some effect on DOE H&R activities that contributed to improved safety awareness, their relationship to the reduced number of reported H&R incidents cannot be verified. In any event, this sitewide trend reversed itself shortly after the DOE workshop, and by August 1994 H&R incidents began increasing to a generally higher level, where it remains today without exhibiting a discernable upward or downward trend.

The trend since 1993 is depicted in Figure 1. While random variations in safety performance are expected, there may be other factors that influence the time interval between incidents, including work stoppages and additional caution for a period following an event; these are discussed in Appendix A. Despite fatalities, suspended operations, and the workshop, there has been no statistically significant change in the frequency of reported H&R occurrences or in the H&R process within the Department.

More incidents can be expected as site cleanup efforts accelerate.

The consequences of H&R incidents can be significant. Approximately three fourths of H&R incidents resulted in an accident where personal injury, property damage, or both was incurred. Although the available information was limited, it appears that in at least 4 percent of the accidents, property damage alone exceeded \$25,000 per accident. While H&R operations and incidents are common to many activities, including testing, fuel movement, and weapons management, the number of H&R operations and incidents is likely to increase as site cleanup efforts accelerate.

DISTRIBUTION OF HOISTING AND RIGGING INCIDENTS

Most hoisting and rigging incidents result from operations involving cranes or forklifts.

Lifting operations utilizing crane equipment generally involve complex maneuvers with large suspended loads. Fifty percent of all H&R incidents analyzed, and 51 percent of all H&R accidents, involved cranes. Forklifts were associated with 31 percent of all H&R incidents and 38 percent of all accidents. Less than 20 percent of all incidents, and 11 percent of all accidents, are associated with "Other" types of H&R equipment, such as manual and power-operated hoists, chainfalls, and block and tackle. The distribution of incidents and accidents associated with H&R operations is summarized in Table 1.

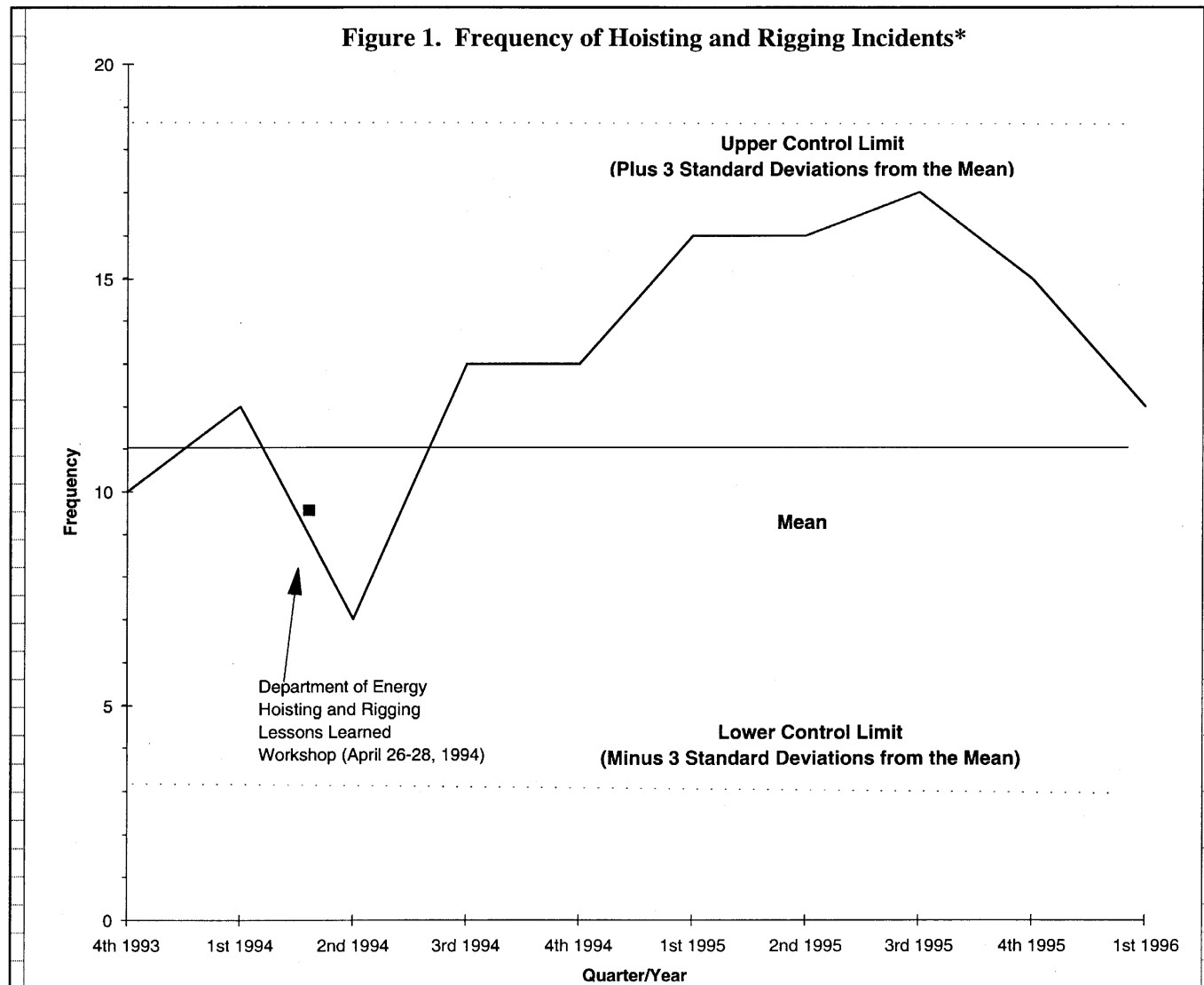
Incidents involving forklifts resulted in an accident more often than those involving cranes or "Other" hoisting equipment. As shown in Table 1, about one third of all incidents involved forklifts, and

Table 1. Distribution of Hoisting and Rigging Incidents and Accidents

Equipment	Number of Incidents	Number of Accidents	Incidents as a Percent of Total*	Accidents as a Percent of Total*	Accidents as a Percent of Incidents*
Crane	66	49	50%	51%	74%
Forklift	40	36	31%	38%	90%
Other**	25	11	19%	11%	44%
Total	131	96	100%	100%	73%

*Rounded to the nearest whole number.

**Includes manual and power-operated hoists, chainfalls, and block and tackle.



Most forklift incidents result in an accident.

90 percent of all forklift incidents resulted in an accident. Generally, tasks using cranes, especially mobile units, involve several people in addition to the operator, such as spotters and signalers. Forklift operations usually require only the operator. Crane operators can generally see the load fairly well, and the additional personnel involved in crane operations augment attentiveness. Consequently, crane operators are better able to control a lift and curtail or suspend operations to avoid an accident. Also, cranes usually transport their loads at a height that is free of obstructions. Forklifts often encounter traffic, terrain, and other physical obstacles during load transportation; these appear to contribute to incidents.

Unlike cranes, forklifts are often used for incidental, non-repetitive tasks.

Discussions with H&R managers and supervisors from DOE, contractor, and subcontractor organizations verified that crane operation is generally a dedicated job, whereas forklifts are operated at various times by a variety of personnel in order to accomplish incidental tasks—that is, a forklift is a "tool." For example, forklifts can both tow like a tractor (which is not considered a H&R-related operation) and hoist like a crane. In this latter (and unconventional) application, a forklift is commonly referred to as a "free-rigger." The forklift tines are used to raise, suspend, and move materials secured by rigging (e.g., ropes, chains, or synthetic web straps). At least two accidents occurred during this review period when forklift equipment was used in an unconventional but acceptable manner. Safe execution of these maneuvers requires experience and proficiency in both forklift operation and crane-related hoisting and rigging techniques.

The complexities associated with crane operations require highly trained personnel who generally gain proficiency through frequent repetition of H&R tasks. Forklift operation, while it does require training, appears significantly less complicated. Because use of this equipment is often incidental and not repetitive, personnel are generally not afforded the opportunity to gain proficiency. Personnel who use forklifts to perform warehousing tasks are an exception. In this environment the forklift is the principal tool, and operators generally receive significant training, perform repetitive tasks, and acquire proficiency. Probably for these reasons, fewer than 23 percent of forklift incidents were associated with warehousing activities.

The use of mobile cranes by subcontractors is expected to increase, heightening the need for effective oversight of subcontractors' safety performance.

Discussions with H&R experts within the DOE (Federal workers, contractors, and subcontractors) indicate that as production-related operations are curtailed and superseded with activities directed at waste management, environmental restoration, and facility dismantlement, the need for stationary or overhead cranes will be reduced, and mobile units will be in more demand. Mobile cranes owned and operated by subcontractors are often used to perform materials handling tasks of varying complexity, whereas overhead cranes are generally operated by contractors and are used to perform maneuvers that are relatively simple and often routine. Independent evaluations performed by the Office of Oversight, in addition to information reported into ORPS and the Department's Computerized Accident/Incident Reporting System (CAIRS), have highlighted deficiencies in oversight of subcontractor activities. Therefore, the additional risks posed as more H&R tasks involving cranes are performed by subcontractor personnel heightens the concern over H&R safety and the need for

effective oversight of subcontractor performance. Information contained in ORPS does not explicitly and formally identify whether an H&R incident is associated with a contractor or subcontractor activity. While it was possible in this review to make this determination for some of the 131 incidents analyzed, it was not possible to resolve this issue for the entire sample.

Nearly half of all incidents involving equipment other than cranes and forklifts resulted in an accident.

"Other" H&R equipment (e.g., hoists, chainfalls, and block and tackle) are not for heavy duty use, as are cranes and forklifts; they are generally used to handle light loads that are not usually classified as critical lifts⁵. Like forklifts, this equipment is used incidentally to performing a task, and personnel operating it are commonly referred to as "incidental riggers." Personnel are usually not highly trained to operate this equipment, do not generally perform repetitive tasks, and are not afforded the opportunity to gain proficiency. Furthermore, the relatively lightweight, uncomplicated, and utilitarian characteristics of "Other" H&R equipment readily lend themselves to unconventional applications. Almost half of all incidents involving non-crane and non-forklift equipment resulted in an accident.

ROOT CAUSES OF HOISTING AND RIGGING INCIDENTS

Human error is the major cause of hoisting and rigging incidents.

Human error, whether directly associated with supervisors or equipment operators, is the principal cause of H&R incidents. Factors not related to human performance, such as equipment failure and weather, are responsible for only 6 percent of H&R incidents. Figure 2 presents information showing that management (35 percent) and personnel errors (33 percent) collectively account for 68 percent of all H&R incidents, as reported into ORPS.

Management shortcomings and workers' inattention to detail account for a large proportion of incidents.

Further analysis shows that deficient work planning (43 percent) and inadequate definition, dissemination, and enforcement of policy (24 percent) are responsible for two thirds of the incidents attributable to management deficiencies. Inattention to detail (56 percent) and not following procedures (28 percent) account for 84 percent of H&R incidents caused by personnel error. (See Figures 3 and 4, respectively.) Furthermore, inattention to detail is the most prevalent cause of all 131 H&R incidents, accounting for about one in every five incidents. Additionally, there are no indications that certain root causes are becoming less frequent over time, are being remedied, or are being replaced with other causal factors.

⁵A lift is designated as critical if: 1) the load requires exceptional care in handling because of size, weight, close-tolerance installation, high susceptibility to damage, or other unusual factors, or 2) collision, upset, or dropping could result in either a) an impact, b) significant release of radioactive or other hazardous materials, or other undesirable conditions, c) undetectable damage that would jeopardize future operations or the safety of a facility, or d) damage that would result in unacceptable delay to schedule or other significant program impact. See U.S. Department of Energy Hoisting and Rigging Handbook, dated June 1995.

Table 2 provides information that can be used to support actions to reduce H&R incidents, based on an analysis of ORPS root cause categories. The data indicate that a generic remedy is not applicable to all H&R situations. For example, while inattention to detail — the single leading cause of all H&R incidents—is responsible for about one in every five crane and forklift incidents, it is associated with less than one in every ten incidents involving "Other" types of H&R equipment (e.g., hoists, chainfalls, block and tackle).

Work planning is a significant factor in non-forklift incidents, while the work environment has more effect on forklift incidents.

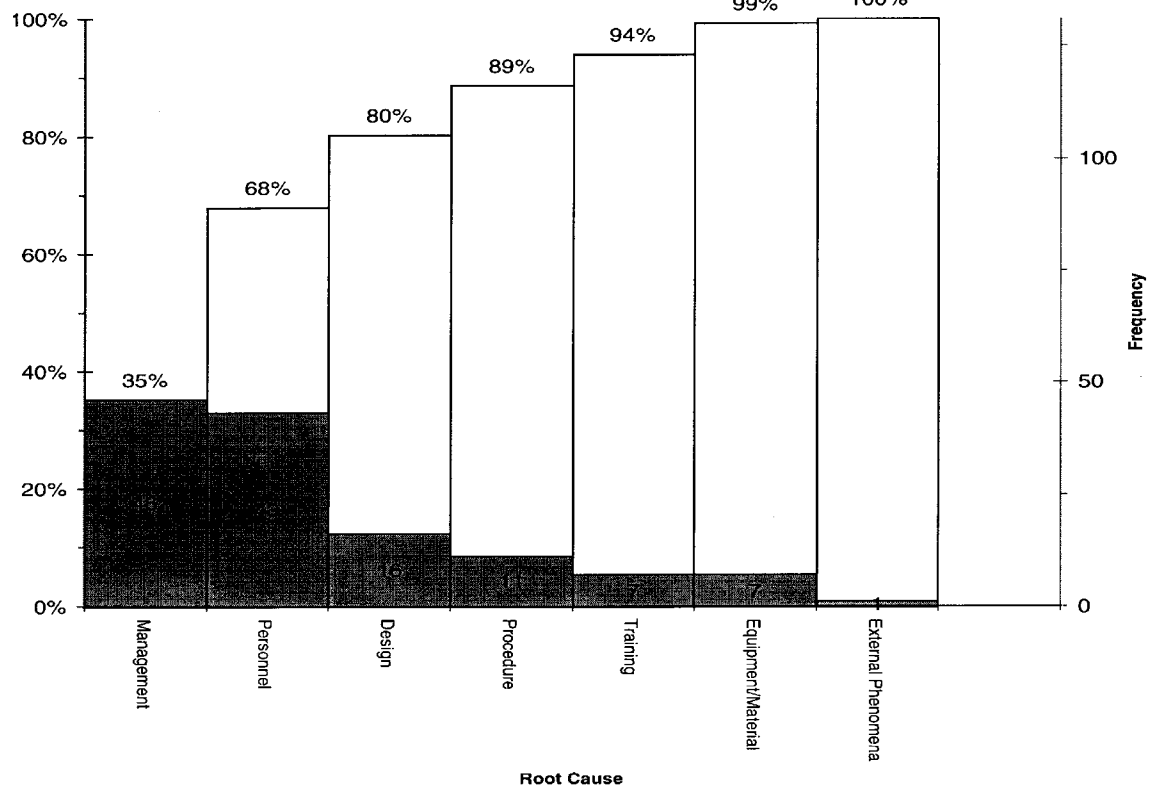
Work organization and planning require more attention in operations involving cranes and "Other" hoisting equipment than when forklifts are utilized. This is evident by the fact that inadequate work planning was the cause of 18 percent of all incidents involving cranes, 27 percent of the incidents involving "Other" hoisting (i.e., non-forklift) equipment, and only 3 percent of all forklift incidents. Similarly, the work environment (i.e., the characteristics of the area in which H&R equipment is operated) has a significantly greater influence on the frequency of forklift incidents than non-forklift incidents. As noted earlier, this is largely due to the mobility of forklifts and the increased likelihood of an incident when forklifts are used to transport loads over routes that are not protected from obstacles or other risks.

Materials handling activities that require the use of "Other" types of H&R equipment, including hoists, chainfalls, and block and tackle, are often initiated on an ad hoc basis and in response to an immediate need to perform a specific task. In these situations, the mechanics of the operation are generally not rigorously addressed, nor is the work well organized and planned. Approximately one in every five incidents involving this equipment is caused by defective engineering design or inadequate configuration of the equipment for the task being performed.

Training-related deficiencies were not identified as a major problem.

Surprisingly, training-related deficiencies were not identified as a significant problem. Procedure-related problems, including applying procedures incorrectly, defective or inadequate procedures, or procedures not used, are responsible for 18 and 20 percent of crane and forklift incidents, respectively. They were not found as causal factors for incidents involving "Other" equipment. Communication, lack of procedures, and defective or failed parts cause incidents with approximately equal frequency for all equipment type categories, although it is the greatest for "Other" equipment (e.g., hoists, chainfalls, block and tackle).

Figure 2. Major Root Causes of Hoisting and Rigging Incidents



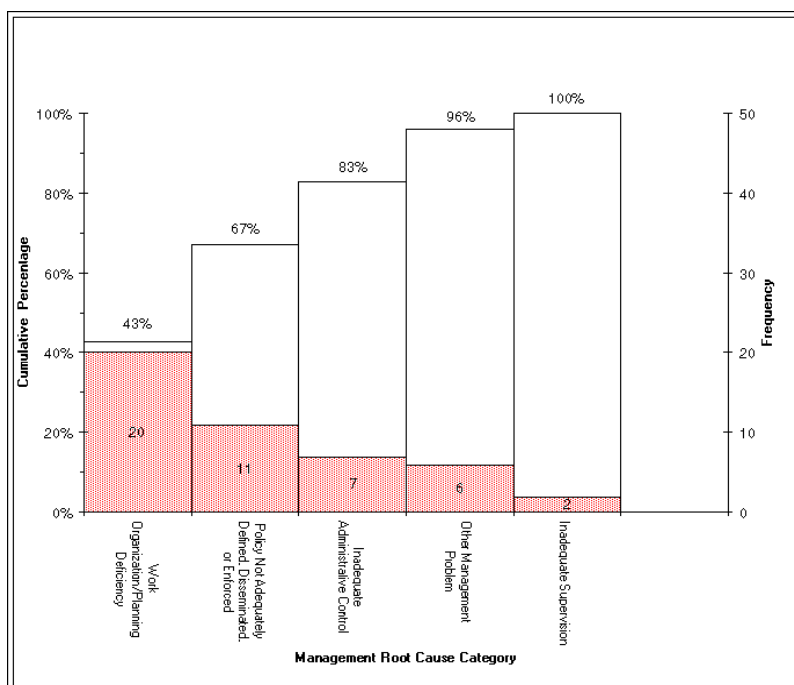


Figure 3. Management Root Cause Categories

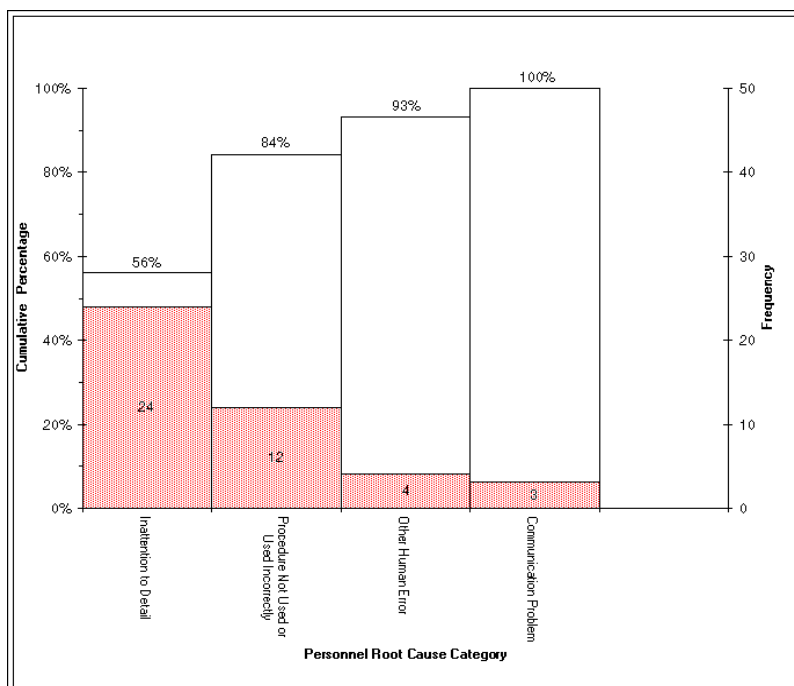


Figure 4. Personnel Root Cause Categories

Table 2. Root Cause of Hoisting and Rigging Incidents by Equipment Type*

Root Cause	Crane	Forklift	Other
Inattention to Detail	20%	23%	8%
Work Organization and Planning	18%	3%	27%
Procedure Not Used or Used Incorrectly	9%	15%	0%
Policy Not Adequately Defined, Disseminated, or Enforced	9%	10%	4%
Inadequate or Defective Design	5%	5%	19%
Defective or Inadequate Procedure	9%	5%	0%
Inadequate Administrative Control	9%	0%	4%
Defective or Failed Part	5%	5%	8%
Other Management Problem	3%	3%	12%
Other Human Error	3%	3%	0%
Inadequate Work Environment	0%	10%	0%
Lack of Procedure	2%	3%	4%
Insufficient Refresher Training	3%	3%	0%
Insufficient Practice or Hands-On Experience	5%	0%	0%
Communication Problem	2%	3%	4%
Inadequate Supervision	0%	3%	4%
Error in Equipment or Materials Selection	0%	3%	4%
Weather	0%	3%	0%
No Training Provided	0%	0%	4%

*Rounded to the nearest whole number.

4.0 CONCLUSIONS

This section presents the major conclusions based on the study results presented in Section 3. These conclusions are applicable Department-wide, and provide a foundation for candidate future actions to improve H&R safety performance.

Management attention is needed to improve the safety of hoisting and rigging operations.

- Despite numerous incidents, accidents, and the lessons-learned workshop, there has been no significant improvement in H&R activities. The manner in which H&R tasks are performed and the associated adverse consequences are consistent with an unchanged process that exhibits expected variations in safety performance. While additional independent oversight may not alleviate the current situation, line management can improve safety by implementing specific actions to change the process by which H&R operations are performed and overseen by line management.

Specific corrective actions depend on the type of equipment being used.

- Root causes of H&R incidents display a strong relationship to the type of equipment used. Thus, management may consider formulating equipment-specific corrective actions to improve H&R safety performance.
- H&R equipment items used incidentally, such as forklifts, are associated with a large proportion of accidents. Effective initiatives by management to address these operations and type of usage will realize significant improvement in H&R safety performance.
- As the Department transitions from production-oriented operations to environmental restoration, greater use of mobile cranes operated by subcontractors can be expected. This situation suggests close evaluation and monitoring by management to limit or prevent H&R incidents and accidents.

APPENDIX A

ANALYTICAL AND STATISTICAL METHODS

INFERENCEAL STRENGTH OF SAMPLE DATA

A narrative search, using the search string `rigg@+hoist@+crane+forklift+sling`, in accordance with the *ORPS User's Manual*, was performed on the entire ORPS database covering reports from January 1, 1988, to March 31, 1996. This process yielded 1,187 occurrence reports relating to H&R; 491 of these were associated with the 30-month period analyzed. Applying the criteria identified in Section 2 of this report to these 491 reports resulted in 131 relevant H&R incidents. Assuming that there were no events that had a significant impact on the reporting level of H&R occurrences throughout this period, proportional analysis can be applied as follows:

$$131/491=X/1187$$

$$X=317$$

It follows then that of the 1,187 occurrence reports in ORPS that relate to H&R, 317 fulfill the aforementioned criteria and represent the population of relevant incidents. Therefore, the 131 incidents analyzed represent approximately 41 percent of the total population (i.e., $131/317 = .41$). This provides a basis for performing an extrapolation and making inferences to the entire population of relevant H&R incidents (317) on the results from analyzing the sample (131).

RANDOMNESS OF VARIATION IN SAFETY PERFORMANCE

A statistical test performed on the data suggests that there is only a 5 percent chance that the variation in the number of incidents over the 30-month period is due entirely to random influences¹. One plausible explanation for this cyclical phenomenon, therefore, is the factors associated with human learning and short term memory. Generally, immediately following an incident there is a short but pronounced period when individuals are most conscious of avoiding the same or similar mistakes; during this time, they demonstrate improved safety performance. Over time, however, without reinforcement (e.g., training, lessons learned, reminders) the sense of urgency and attentiveness generated by the incident declines, and poor safety habits resurface. Eventually, an incident occurs and the cycle repeats itself.

CONSTRUCTION OF CONFIDENCE LIMITS

Inferences about the population of relevant H&R incidents (317) contained in ORPS can be made based on the sample (131) with a conservative degree of confidence. Table A-1 contains a summary of confidence limits for significant sample statistics, corresponding to the .95 confidence coefficient.

¹The theory of runs from H.T. Davis, *The Analysis of Economic Time Series*, pp. 164-170, was applied to test the null hypothesis that the cyclical variation is random. A chi-square test was significant at the .05 level, indicating that there is a 95 percent probability that the cyclical variation is not due to chance.

For example, the table shows that while 50 percent of the 131 sample incidents analyzed involved cranes, one can be 95 percent confident that the proportion for the total population of 317 relevant incidents contained in ORPS lies in the interval between 41 and 59 percent. Similarly, one is 95 percent confident that between 27 and 43 percent of all relevant H&R incidents contained in ORPS are due to management deficiencies, and that between 11 and 25 percent are caused by inattention to detail. Establishing confidence limits puts the utility of the sample results in perspective. Confidence limits help highlight general conclusions and, more importantly, aid in the selection process used to implement discrete recommendations. The established confidence interval around the H&R sample statistics can be used to determine best, median, and worst case scenarios when quantifying impacts of alternative safety improvement strategies — e.g., performing benefit-cost and cost-effectiveness analyses. Proposed actions to limit or prevent H&R incidents and accidents are generally analyzed with respect to expected outcomes that are consistent with established confidence limits.

Table A-1. Approximate 95 Percent Confidence Limits for Selected Sample Statistics

Parameter	Sample Statistic	Lower Confidence Limit*	Upper Confidence Limit*
Crane Incidents as a Percent of Total	50%	41%	59%
Forklift Incidents as a Percent of Total	31%	23%	39%
Crane Accidents as a Percent of Total	51%	42%	60%
Forklift Accidents as a Percent of Total	38%	30%	46%
Management Deficiency	35%	27%	43%
Personnel Error	33%	25%	41%
Inattention to Detail	18%	11%	25%
Work Organization and Planning	15%	9%	21%
Procedure Not Used or Used Incorrectly	9%	4%	14%
Policy Not Adequately Defined, Disseminated, or Enforced	8%	3%	13%

*Calculated using the normal approximation to the binomial distribution.

APPENDIX B

TEAM COMPOSITION

Deputy Assistant Secretary, Oversight: Glenn S. Podonsky

Associate Deputy Assistant Secretary: Neal Goldenberg

Director, Office of Oversight Planning and Analysis: Rebecca F. Smith

Deputy Director, Office of Oversight Planning and Analysis: Frank B. Russo

Analyst: David M. Berkey