CDC Workplace Safety and Health

NIOSH ALERT

Preventing Worker Injuries and Deaths from Mobile Crane Tip-Over, Boom Collapse, and Uncontrolled Hoisted Loads

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

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WARNING!

Construction and industrial workers are frequently injured or killed when working on or around mobile cranes because of tip-over, boom collapse, and uncontrolled hoisted loads.

The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing injuries and deaths of workers exposed to mobile crane tip-over, boom collapse, and uncontrolled hoisted loads. Recent NIOSH investigations suggest that workers may not fully recognize the hazards associated with operating or working near mobile cranes. Crane tip-overs can result from operating a crane outside the manufacturer's recommended safe lifting capacity. Booms can collapse for reasons such as overloading, improper disassembly procedures, and improper rigging. Both crane tip-over and boom collapse can result in workers being struck by parts of the crane or uncontrolled hoisted loads.

This Alert describes six incidents resulting in the deaths of eight workers and injuries to two others that were either working near or operating mobile cranes. In each incident, these injuries or deaths could have been prevented by using proper safety procedures such as not exceeding the crane's lift capacity; following proper set-up, maintenance and dismantling procedures; and not working under a suspended load.

NIOSH requests that the information in this Alert be brought to the attention of all employers, managers, supervisors, crane operators, riggers, and ground workers in companies that own or rent mobile cranes. NIOSH requests assistance from safety and health officials, construction companies, unions, crane and rigging manufacturers, crane rental facilities, building material suppliers and manufacturers, editors of trade journals, and those positioned to communicate prevention information to employers and workers.

BACKGROUND

Mobile cranes are used to hoist loads to meet various construction and industrial needs. All cranes use cables and pulleys or hydraulics to raise and lower the desired load. The Construction Safety Association of Ontario's Mobile Crane Manual [Dickie 1999] lists the basic operational characteristics of all mobile cranes as follows:

- Ability to lift and lower loads
- Ability to swing loads around an axis of rotation
- Adjustable boom lengths
- Adjustable boom angles
- Ability to travel about the job site under their own power

Mobile cranes come in a variety of types and configurations such as the following:

- Boom trucks
- Industrial cranes
- Carrier-mounted lattice boom cranes
- Crawler-mounted lattice boom cranes
- Carrier-mounted telescopic boom cranes
- Crawler-mounted telescopic boom cranes
- Rough terrain cranes
- Mobile tower cranes
- Heavy-lift mobile cranes

Cranes are able to lift heavy loads by applying the principle of leverage. The crane's own weight is balanced against the object or load being hoisted at the tipping point (or tipping axis) [Figure 1]. The crane remains stable and can safely lift and move the load so long as the crane's leverage on the load is greater than the load's leverage on the crane [Dickie 1999].

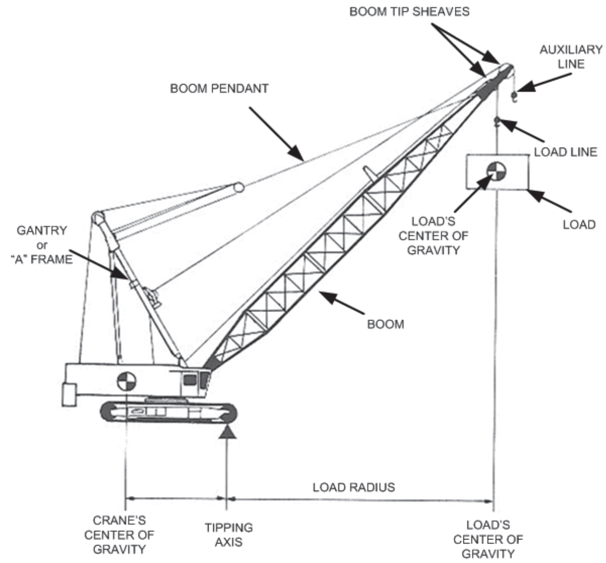

Figure 1. Key components of a typical crawler-propelled crane. The crane's weight is balanced against the weight of the lifted load. The diagram is courtesy of the Construction Safety Association of Ontario and may not be reproduced without their written permission.

The crane's ability to lift a heavy load, swing it in any direction, and raise it high overhead also contributes to the many reported incidents of crane tip-over when the cranes are not set up correctly or proper procedures are not followed. During a lift, the distance from the load's center of gravity to the crane's tipping axis changes as the boom angle changes, the boom is extended, and as the crane's upper deck rotates to swing the load. These changes can lead to instability if the crane's lift capacity is exceeded. Proper inspection, setup, and operation by the crane operator, along with proper maintenance, are necessary to ensure safe crane operation.

A crane's lifting capacity is reduced as the boom is lowered because the distance from the load's center of gravity to the tipping axis is increased. Increasing the load's distance to the tipping axis reduces the ability of the crane's weight to counteract or "leverage" the load's weight.

Extending the boom at any given angle has the same effect.

A crane is a complex machine requiring considerable knowledge for safe operation. This knowledge can only be gained through proper training and hands-on experience. The ability to understand and correctly use a crane's load chart is critical to the safe operation of a mobile crane. Each crane's load chart specifies the rated (maximum) capacity of that machine for every permissible configuration. The load chart also specifies the machine's operational limitations and conditions necessary for safe operation. An operator must always use these load charts to determine capacity for a lift and know or be able to calculate the weight of each load. Modern cranes may incorporate computerized load-moment indicators (LMI), which monitor hoisting data and provide the crane operator with a readout of lift conditions. These LMI devices may be designed to interrupt the hoist operation when the hoisted load reaches a set limit to prevent crane overloading. These devices require periodic maintenance, verification, and recertification by a knowledgeable person. LMI devices are not intended to take the place of a load chart. The LMI alone does not ensure a safe lift; it is simply an indicator to advise a competent operator of load parameters to consider when making operational judgments during the lift [Shapiro 2000].

A number of factors are involved with making a safe lift. For example, if a crane is equipped with outriggers, it is strongly recommended that they be fully extended to the manufacturer's specifications and used on every lift following load capacity charts supplied by the manufacturer, regardless of the weight of the load. If all outriggers are not fully extended, lift capacity drops sharply [Dickie 1999; Shapiro 2000; ASME 2004]. Unless the manufacturer has supplied specific load charts for partial outrigger extension, load charts designated for *on rubber* or *lifting without outriggers deployed* must be followed [AEM 2002].

Cranes must be located on solid, stable ground capable of supporting the weight of the crane plus the suspended load. Crane operators often encounter ground at the construction site that has recently been worked or backfilled. A professional engineer should evaluate such conditions to ensure that ground pressures generated by the crane's weight do not exceed the load-bearing capacity of the soil. Extreme caution is needed to ensure cribbing blocks placed under outrigger pads are firmly supported and of adequate size. When multiple lifts are made from the same location, the condition of the ground and the blocking under the outrigger pads should be checked often to ensure the timbers have not shifted or deteriorated. Some companies use long bolts to join cribbing timbers together to create a more solid base for outriggers to set on, thus preventing timber rollout.

A mobile crane mounted on a barge acts differently than when being operated on land [Shapiro 2000]. This phenomenon is due to the way in which forces applied to the crane by the weight of the lift are transmitted to the barge. When a barge-mounted crane lifts a load that is not on the barge, the forces applied to the crane are transmitted to the barge and the barge will lean toward the load. Landing a load (resting the load on the ground or another surface) causes the barge to momentarily lean away from the load as the forces applied to the crane are reduced. This leaning or tilting of the barge is known as *list*. Lifting a load that is already on the barge can also cause the barge to list when the crane swings or changes the boom angle, changing the equilibrium between the weight of the crane and the weight of the load. The listing of the barge will also cause the suspended load to swing. The crane operator must expect and compensate for this swinging motion.

Proper maintenance is important to ensure cranes operate safely and efficiently. The Mobile Crane Manual [Dickie 1999] lists a number of factors that contribute to poor crane performance and reduce a crane's rated capacity. These factors include lack of proper maintenance, machine configuration not in compliance with manufacturer's specifications, eccentric reeving of cables, and excessive duty cycle operations.* Eccentric reeving occurs when the hoist line is not centered over the boom tip and causes torque (twisting) in the boom. Load charts only apply when the boom is symmetrically rigged (load line centered). Follow the manufacturer's specifications when reeving cables.

The North Carolina Department of Labor estimates that one crane upsets (tips over) during every 10,000 hours of crane use in the United States [NC DOL 2004]. Nearly 80% of all crane upsets (tip-overs) are attributed to operators exceeding the crane's operational capacity [Kay 2004]. Approximately 54% of these incidents are the result of swinging the boom or making a lift without the outriggers fully extended [NC DOL 2004; Kay 2004].

*__*Duty cycle*__: Steady work at a fairly constant short cycle time with fairly consistent loading levels for one or more daily shifts.

Critical Lifts

NIOSH and others have identified certain types of hoisting operations that require special considerations to ensure worker safety. In the crane and rigging community, the term *critical lift* is commonly used to describe these situations. A critical lift generally identifies hoisting operations for which the margin for error is reduced. Critical lifts include the following situations:

- The weight of the hoisted load approaches the crane's maximum capacity (70% to 90%).
- Two or more cranes simultaneously lift the same load.
- Personnel are being hoisted.
- Nonstandard or specially modified crane configurations are used.
- Special hazards are associated with the lift, such as
  - — the crane is located inside an industrial plant;
  - — the crane(s) is mounted on floating barges;
  - — loads are lifted close to powerlines; and
  - — high winds or other environmental conditions are present.

However, the definition of a critical lift is not as important as the planning necessary to safely perform the lift.

Load ratings developed by crane manufacturers are based on the principal factors affecting crane stability and include the weight of the hoisted load, the structural strength of the crane, and the crane's boom length and load-radius. Crane load charts specify maximum lifting capacities for every configuration permitted by the manufacturer and specify the limitations and conditions necessary for safe operation [Dickie 1999]. These ratings are based on crane operation under ideal conditions. The actual hoisted load includes the weights of the lifted materials, hook block, slings, and other lifting accessories. However, additional loads may be imposed on the crane by factors present in the work environment. These factors may include wind forces acting on the crane structure and the lifted materials, dynamic forces due to movement of the crane and lifted materials, and side loads due to out-of-level or unstable ground conditions [Dickie 1999; Shapiro 2000]. When a hoisted load exceeds 85% to 90% of a crane's rated capacity, little reserve is available to counter unanticipated loads.

Special hoisting precautions are necessary to ensure worker safety during critical lifts [Dickie and Hardy 2000]. Critical lifts should follow engineered lift plans that are based on a comprehensive evaluation of the most accurate information available for all factors affecting crane stability. Critical lift plans should be in writing [Ritchie 2005]. Because a thorough understanding of the relationship between the crane design and the dynamic effects of traveling and moving with hoisted loads is crucial to the development of these plans, the plan should be designed by a registered professional engineer specializing in hoisting operations [NIOSH 1999]. Currently, several Federal agencies require written lift plans for critical lifts conducted under their jurisdiction, including the U.S. Army Corps of Engineers, Department of the Army [DOA 2003], the U.S. Department of Energy (DOE) [DOE 2004], the National Aeronautics and Space Administration (NASA) [NASA 2002], and the U.S. Navy [Navy 2003].

To prevent crane tip-over, the critical lift plan should be based on the operational limitations specified by the crane load chart, measured (as opposed to calculated) weights for the materials to be hoisted, thorough studies of wind speed and its effect on the crane and hoisted load, and consideration of the effects of ground conditions and dynamic forces on the crane's stability.

INJURY DATA

The Census of Fatal Occupational Injuries (CFOI) is a multisource data system maintained by the U.S. Bureau of Labor Statistics (BLS) to identify work-related deaths in the United States. A NIOSH review of CFOI data identified 719 cases between 1992 and 2002 in which a mobile crane[†] was the primary or secondary source of a fatal injury [NIOSH 2004]. Incidents in which the victim was struck by an object such as an uncontrolled hoisted load or part(s) of a mobile crane accounted for 290 (40.3%) of these fatalities (Table 1). Electrocution fatalities due to cranes contacting overhead power

[†]The following occupational injury and illness source codes for cranes were included: unspecified (3430); floating (3431); hammerhead (3433); mobile, truck, and rail mounted (3434); portal, tower, and pillar (3437); and N.E.C (3439). These specific codes were selected to limit the analysis to types of mobile cranes. Excluded crane types include gantry (3432); monorail and underhung (3435); overhead (3436); and storage and retrieval hoist systems (3438).

lines or other electrical sources accounted for 173 (24.1%) of the 719 CFOI cases. A previous NIOSH Alert [NIOSH 1995] addressed crane-related electrocution hazards. This Alert primarily addresses injuries and deaths when workers are struck by falling or swinging objects resulting from crane stability issues related to tip-over, boom collapse, and uncontrolled hoisted loads. According to CFOI data, 153 (52.8%) of 290 mobile crane-related fatalities in which the victim was struck by an object (such as an uncontrolled hoisted load or crane part) occurred in construction. Forty-four (15%) occurred in manufacturing (Table 2).

Table 1. Events resulting in mobile crane-related occupational injury deaths: United States, 1992–2002

	Number of deaths	Percent
Struck by falling or swinging object (e.g., crane part or hoisted load)	290	40.3
Contact with electrical current (e.g., overhead power lines)	173	24.1
Fall from crane structure or cab	88	12.2
Transportation (e.g., moving crane from site to site)	76	10.6
Caught in crane moving parts	73	10.2
Other	19	2.6
Total	719	100.0

Table 2. *Struck by* mobile crane-related occupational injury deaths by industry: United States, 1992–2002

	Number of deaths	Percent
Construction	153	52.8
Manufacturing	44	15.2
Transportation and public utilities	35	12.0
Services	20	6.9
Wholesale trade	14	4.8
Mining	12	4.1
Agriculture, forestry, and fishing	6	2.1
Other	6	2.1
Total	290	100.0

CURRENT STANDARDS

Occupational Safety and Health Administration (OSHA)

Mobile crane and hoisting hazards are addressed by the following OSHA standards found in Title 29 CFR[‡]: general industry (29 CFR 1910.180), maritime (29 CFR 1918.66), marine (29 CFR 1917.45), longshoring, and construction (29 CFR 1926.550).

These Federal standards cover a wide range of safety issues including procedures for safe crane operation, posted instruction and warning signs, daily and annual crane inspections, maintenance, wire rope and cable requirements, clearance from overhead energized power lines, and the use of spotters. Current Federal standards do not consider crane-hoisting circumstances with reduced margin for error such as operating at or near crane capacity, operating without outriggers fully extended, operating on unstable ground conditions, etc.

Title 29, CFR 1910.180 and 1926.550 require rated load capacities, recommended operating speeds, special hazard warnings, and instructions to be conspicuously posted on all equipment and visible to the operator while at the control station. Title 29, CFR 1910.180(e)(2)(ii) requires that test loads must not exceed 110% of the rated capacity for a particular boom length and radius.

In June 2003, OSHA established a committee of experts representing crane operators, owners, manufacturers, and other interested parties to revise the construction industry standard covering cranes and derricks (29 CFR 1926.550), using a negotiated rulemaking process. This committee addressed key issues such as crane inspection and testing, record keeping requirements, crane operator certification, work near energized power lines, the use of qualified signal persons and spotters, and working under suspended loads. In July 2004, OSHA announced this consensus draft regulation was submitted to the Assistant Secretary of Labor for Occupational Safety and Health for promulgation through the Federal rulemaking process [DOL 2004].

Certification and Licensure

Current Federal laws do not require crane operators to be licensed or certified. At present, 12 States and 6 cities require crane operators to be licensed[§]. Certification is usually a voluntary process initiated by a nongovernmental agency through which people are recognized for their knowledge and skill. Licensing is more restrictive and usually refers to mandatory governmental requirements based on a combination of examination, testing, and demonstration of the appropriate skills, knowledge, and experience [NCCCO 2004].

The draft regulation for crane and derrick safety in construction submitted by the negotiated rulemaking committee to OSHA

[‡]*Code of Federal Regulations*. See CFR in references.

[§]States that require licensure: California, Connecticut, Hawaii, Massachusetts, Montana, Nevada, New Jersey, New Mexico, New York, Oregon, Rhode Island, West Virginia. Minnesota has pending legislation scheduled to take effect in 2006. Cities that require licensure: Chicago, Los Angeles, New York, New Orleans, Omaha, Washington, DC.

requires crane operator testing and certification. Employers should consider implementing an operator testing and certification program even before this new requirement becomes law.

ANSI/ASME

The American National Standards Institute (ANSI) has approved and designated the ASME B–30.5 Safety Standard for Mobile and Locomotive Cranes, developed by the American Society of Mechanical Engineers (ASME) as an American National Standard in August 2000. This standard was revised in 2004 [ASME 2004] and is one of a series of safety standards that are collectively known as the ANSI Safety Standard for Cableways, Cranes, Derricks, Hoists, Hooks, Jacks, and Slings.

ASME B30–5, Chapter 5–2, Section 5–2.4 and the Society of Automotive Engineers (SAE) J959–1966 standards specify requirements for wire rope and cable inspection, replacement, and maintenance when used on cranes to hoist loads.

ASME B30.5, Chapter 5–3, Section 5–3.3 identifies standard hand signals to be used by spotters to signal crane operators during the lift cycle (see Appendix A).

Fair Labor Standards Act

The Fair Labor Standards Act (FLSA) is the primary law governing workers under age 18. FLSA prohibits work for youths under age 18 in occupations declared by the Secretary of Labor to be especially hazardous—Hazardous Orders (HO). Youths under age 16 are prohibited from working in construction and manufacturing under Child Labor Regulation No. 3 [29 CFR 570.33(a) and (f)(4)]. Hazardous Order No. 7 *(Power-Driven Hoisting Apparatus)* prohibits anyone under age 18 from performing “work of operating an elevator, crane, derrick, hoist…”, as well as “work of assisting in the operation of a crane, derrick, or hoist performed by crane hookers, crane chasers, hookers-on, riggers, rigger helpers, and like occupations.” Other types of work that are prohibited for workers under age 18 that frequently involve the use of cranes include demolition (HO 15), roofing (HO 16), and excavation (HO 17) [DOL 2001]. For more information, refer to DOL Fact Sheet No. 043 Child Labor Provisions of the Fair Labor Standards Act (FLSA) for nonagricultural types of work [DOL 2002].

CASE REPORTS

The following cases were investigated by the NIOSH Fatality Assessment and Control Evaluation (FACE) program and NIOSH-supported, State-based FACE programs. The cases were selected to present a variety of circumstances in which workers were fatally injured because of mobile crane tip-over; boom collapse caused by improper disassembly and improper reeving; or contact with the hoisted load. Through 2005, the FACE program investigated 22 incidents in which workers were fatally injured because of crane tip-overs, collapse, or uncontrolled hoisted loads. Complete FACE reports are available on the NIOSH Web site: www.cdc.gov/niosh/face.

Case 1

On July 14, 1999, 3 male ironworkers (the victims), ages 39, 40, and 52 died after falling approximately 300 feet to the ground when the suspended personnel platform they were occupying was struck by the uncontrolled load of a heavy-lift crane (Figure 2).

Figure 2. Heavy-lift crane after tip-over at stadium project. *(Photo courtesy of John Thraen)*

Figure 3. Crane tip-over at library expansion project. *(Photo courtesy of The Blade/Toledo Ohio)*

The victims were working in windy conditions during the construction of a county sports stadium. The firm responsible for the assembly and erection of the stadium roof had contracted with the victims' employer to provide ironworkers and had also contracted with a multinational contractor for the use of a heavy-lift crane. The 3 ironworkers were suspended above the ground to observe the hoisting of a 450-ton roof section. The roof section had been hoisted to about 330 feet and transported over its connection location by the heavy-lift crane crew. As the roof section was being lowered into place, the heavy-lift crane began to tip over. The crane continued tipping and the roof section collided with the personnel platform, knocking it and the victims to the ground. Evaluation of investigative information indicated that the weight of the hoisted load, side loads from wind, out-of-level ground conditions, and the swinging motion of the hoisted load as the crane moved sideways combined to tip the crane [NIOSH 1999].

Case 2

On October 13, 1999, a 50-year-old male carpenter at a municipal construction site died after he was struck by a loaded concrete bucket during a crane tip-over (Figure 3). The victim was removing forms from a newly constructed concrete wall while a concrete finishing crew was filling empty forms approximately 20 feet away. Concrete was being hoisted from street level with a crawler-mounted mobile crane and landed under the direction of a roof-top spotter. The victim's employer had contracted with a crane rental company to supply the crane and a certified crane operator with 26 years of experience. As the crane operator hoisted a 1-cubic-yard bucket load of concrete, swung it over the roof, and boomed out toward the empty forms, the crane lost stability, tipping toward the victim. When the crane operator realized the crane was tipping, he radioed a warning to the spotter who yelled out a warning to the roof-top workers. The victim had just started to react when the uncontrolled concrete bucket swung toward him, striking his head and shoulder. The victim was pronounced dead at the scene from blunt force head and chest injuries. Evaluation of the crane configuration, the distance of the intended landing site from the crane's center pin, and the manufacturer's load chart indicated that the crane's recommended capacity had been exceeded. In addition, investigators found that the crane's LMI had been known to indicate false readings in the past and had not been repaired/recalibrated. This malfunctioning

LMI may have contributed to the incident by providing the operator with false information [NIOSH 2000].

Case 3

On October 8, 1997, a 56-year-old truck driver was crushed when a crane tipped over and the crane's boom landed on the cab of the dump truck in which he was sitting (Figure 4). The 50-ton, all-terrain crane had been set up near the access road to a construction site in preparation for unloading components of a tower crane that would soon arrive on-site. The crane operator had set up parallel to the access road and had fully extended the crane's left outriggers. The right outriggers had been set but not fully extended, as they would have blocked truck access to the construction site. This set-up was intended to be temporary until building materials and equipment could be moved to make more room for the all-terrain crane. The crane operator began to clear the area by lifting an empty 4-yard concrete bucket over the rear of the crane. The operator swung the bucket over the right side of the crane, moving it between the victim's truck and another truck waiting in line. As he swung the crane's boom to the right, he also began to "boom down" to extend the load radius for more clearance (i.e., lowered the crane boom to increase the distance between the load and the crane's center of rotation). When the bucket reached the area near the right front fender of the victim's dump truck, the operator lowered it to the ground. The crane tipped toward the load. The operator attempted to regain stability by lowering the bucket more quickly, but was unable to drop it fast enough, and the crane continued to tip. The crane's boom hit the truck cab directly over the driver's seat, pushing the roof onto the victim and crushing him forward in the seat. Measurements taken after the incident showed the crane's load lift capacity had been exceeded for the boom length and angle used [NIOSH 1998].

Figure 4. Crane tip-over at construction site. Note that the right outriggers were set, but not extended. *(Photo courtesy of OSHA)*

Case 4

On December 14, 2000, a 38-year-old stevedore (the victim) was fatally injured while working at a river-port materials-handling facility after being struck by the collapsing boom of a mobile crane (Figure 5). The victim and a coworker had been previously lowered from the dock level via a crane-suspended personnel platform and landed on a barge. After they had disembarked from the personnel platform, the port manager, who was operating the crane, began to hoist it back to the dock. The platform had reportedly been raised about 2 feet when the right-side boom pendant (cable supporting the boom) rode out of the boom tip pendant sheave, immediately introducing 200 feet of slack into the boom-hoist system and causing the boom to fall. The victim apparently observed the boom falling and pushed his coworker out of the way. The boom hit the edge of the dock, broke over the dockside,

Figure 5. Boom collapse at river facility. *(Photo courtesy of OSHA)*

Figure 6. Mobile tower crane tip-over attempting to hoist water tank. *(Photo courtesy of Iowa FACE Program)*

and struck the victim. Investigation after the incident revealed that ice that had formed on the boom pendants during a recent severe storm, built up at the boom pendant sheaves, and forced the boom pendants to ride out of the sheave, allowing the boom to become unsupported [NIOSH 2001].

Case 5

On July 20, 2000, a 29-year-old worker for a water tank company was killed when the partially assembled water tower he was working on was struck by a portable tower crane as it overturned (Figure 6). The victim was part of a three-man crew that reconditions and relocates used water towers. A crane company had been hired to help the crew erect the water tower supports and lift the tank to its final position on the tower. Two months before the incident, the ground in the construction area had been graded, compacted, and certified for a load of 2,000 pounds per square foot. When the crane was set up, the front and rear outriggers had been set on timbers resting directly on the ground. No plywood or steel plates were used under the timbers to distribute the load, nor were bolts or other rigging used to secure the timbers together. The victim was sitting on a horizontal strut of the water tower base, approximately 80 feet in the air, preparing to adjust and tighten rod braces once the tank had been set in position. After the operator had hoisted the empty 28,000-pound tank to about 130 feet and was swinging it into position over the tower, the crane's rear outrigger facing the water tower slipped between the cribbing timbers and sank into the ground. The tower crane and its load fell, striking the tower. The victim was killed during the tower collapse. During the incident, two others were injured: a member of the tank crew positioned inside the water tower ladder cage and the crane operator inside the crane's operating station [Iowa FACE 2000].

Case 6

On March 17, 1997, a 42-year-old master mechanic was fatally injured while dismantling a crane boom (Figure 7). The victim and two coworkers were dismantling the crawler-mounted lattice boom crane in preparation for transport. The crane boom had been lowered to 8½ feet off the ground and was supported by the boom pendants. The victim positioned himself under the pinned connections between the inner (heel or

Figure 7. Boom collapse during crane disassembly.

base) section and the center section of the boom. The victim removed the pins from the bottom connections. When the victim removed the last of the two pins, the boom sections fell, striking and pinning the victim underneath [NIOSH 1997].

CONCLUSIONS

Proper training of crane operators in the mandatory use of load charts is important for safe hoisting operations. Crane operators need to know and understand how to use load charts provided by the crane manufacturer. LMI devices are an important safety feature on modern cranes. However, these devices cannot replace the judgment of a trained and qualified operator who has knowledge of safe practices regarding hoisted loads, swing radius, and load chart information. LMI devices should be checked per the manufacturer's recommendations and if not working properly, tagged out-of-service until repairs are made.

Crane operators and workers must follow the manufacturer's recommendations for crane set-up and rigging.

Workers must use caution so that they do not place themselves in dangerous areas where they can be struck by falling loads or by falling or collapsing crane components.

Managers and safety professionals need to consider safe work practices for workers who are required to work on or near operating cranes. All workers should use and follow established hand signals such as the standard hand signals listed in ANSI B30.5–2004 (see Appendix A).

RECOMMENDATIONS AND DISCUSSION

NIOSH recommends that employers, workers, and crane rental companies take the following actions to minimize the risk of injury and death to those who work on or near mobile cranes:

Employers

- **Make sure your work sites comply with safety requirements found in pertinent regulations and standards including OSHA 29 CFR 1910.180 (general industry cranes); 29 CFR 1917.45 (marine terminals); 29 CFR 1918.66 (maritime, cranes and derricks other than vessel's gear); 29 CFR 1926.550 (construction industry cranes and derricks); and ASME B30.5–2004, mobile and locomotive cranes.**
    - — Inspect and maintain each crane following the manufacturer's recommendations.
    - — Make sure operators are properly trained and qualified.

— Coordinate communications between the crane operator and riggers, spotters, supervisors, and others working near the crane.

— Use standard hand signals and provide training for signal persons (see Appendix A).

— Follow manufacturer's guidelines for crane assembly and disassembly.

— Make sure wire rope is in good working order.

— Keep workers clear of hoisted loads.

— Follow safe work practices when working near energized power lines.

- **Conduct training to ensure that crane operators understand safe crane operation (for example, reading and comprehending load charts) as well as the principles of set-up, rigging, hoisting, extending the boom, swinging a load, pinching and crushing points, swing radius warning barriers, power line safety, etc.**

  — Consider requiring operator testing and certification as a prerequisite for employment, even if not required by law.

  — Consider using fatality case reports in your training programs.**

  — Include principles of crane operation, such as the fact that raising and lowering the boom changes the distance from the load's center of gravity to the tipping axis of the crane.

- **Review your occupational safety programs and standard operating procedures to ensure that they include safe practices for lifting loads.**

- **Conduct training to ensure that riggers and ground workers understand the hazards of working around mobile cranes and that they remain vigilant and watch for signs of problems at all times, especially if power lines are nearby.**

  — Use a spotter whenever the crane operator's view of the lift area, swing radius, or the landing area is obstructed.

  — Notify workers before a lift begins.

  — Make sure workers are not located within the swing radius or under a suspended load at any time.

  — Thoroughly evaluate ground conditions, wind speed, travel distance, proximity to overhead power lines, and other obstructions.

  — Follow all pertinent OSHA regulations.

  — Follow manufacturers' recommendations for safe crane operation and maintenance.

- **Develop and follow a written engineered lift plan for all critical lifts.**

  — Make sure that critical lift plans are (1) developed by registered professional engineers with specialized knowledge of hoisting operations and (2) based on a thorough evaluation of the following:

    - The rated capacity and operational limitations specified by the crane's load chart [NIOSH 1999]
    - Measured (as opposed to calculated) weights for the materials to be hoisted [NIOSH 1999]

**The NIOSH Web site www.cdc.gov/niosh/face is one source of fatality case reports.

- Thorough studies of wind speed and its effect on the crane and hoisted load [NIOSH 1999]
- Consideration of the effects of ground conditions and dynamic forces on the crane's stability [Dickie and Hardy 2000; Shapiro 2000; NIOSH 1999]

— Include specifications for communication during the lift. All parties involved in the lift, including crane operator(s), riggers, signal persons, and supervisors must have a thorough understanding of how communication will take place [Dickie and Hardy 2000].

— Identify a single person to direct all operations during the lift [Dickie and Hardy 2000; NASA 2002; DOE 2004].

- **When multiple lifts are made from one location, such as during duty cycle operations, check the condition of the ground and blocking materials regularly and as often as possible to ensure the crane remains on firm stable ground.**

— Watch for signs of soft or unstable ground compressing or deflecting (pushing out) from underneath blocking due to the downward pressure exerted by the crane's outriggers or the crane's tracks or wheels.

— Watch for signs of previously level or unsecured cribbing blocks rolling out from under the outrigger pads.

— Do not exceed the manufacturer's recommended load chart.

— Pay special attention when working around construction and excavation sites, backfilled areas, underground drains and culverts, poorly drained areas, and sandy soils.

— When in doubt, have the stability of the ground evaluated by a qualified professional engineer to ensure the area will support the weight of the crane plus the suspended load over the entire lift cycle.

- **Make sure mobile cranes located on floating barges are positively secured to the barge and barge list is accounted for when determining safe load capacity.**

— Reduce load rating charts whenever list exceeds 1 percent [Shapiro 2000]. Consult the crane manual or crane manufacturer for chart reductions and maximum list for the crane configuration.

— Positively secure mobile cranes located on floating barges according to OSHA standard 29 CFR 1926.550(f)(1)(iv).

- **Follow the manufacturer's recommended assembly and disassembly and maintenance procedures when working on cranes.**

— Use proper blocking methods to adequately support crane components during these operations.

— Block boom sections under each section's support members to ensure the weight of the section is safely supported.

— Do not block between the support members, as this may cause damage to the boom section.

— Always check to ensure boom pendants (boom suspension cables or lines) are properly located before removing a connecting pin. The boom pendant should be between the pin and the crane body so that it supports the boom section closest to the crane body.

— When removing pins, block or support the remaining boom section(s) to prevent their collapse. Refer to the manufacturer's recommendations for long booms and booms with jibs.

- **Comply with child labor laws that prohibit construction and manufacturing work by persons under age 16 and that prohibit workers under age 18 from operating or assisting in the operation, repair, servicing, assembly, disassembly and similar activities associated with mobile cranes. For more information about Federal child labor laws, visit www.dol.gov/dol/topic/youthlabor/index.htm; or call 1–866–4–USADOL.**

— Do not assign workers under age 16 to any aspect of construction or manufacturing work.

— Do not assign workers under age 18 to work as crane operators or to perform any crane maintenance, set-up, assembly or disassembly operations.

— Make sure all workers are aware of any workers under age 18 in the work setting. Inform them about the types of work young workers are allowed to perform and where they should report questionable tasks.

— Consult a U.S. Department of Labor Wage and Hour Division office for assistance, if needed. For information about Federal child labor laws, visit www.dol.gov/dol/topic/youthlabor/index.htm or call 1–866–4–USADOL. For links to State labor offices, visit www.ilsa.net or www.youthrules.dol.gov/states.htm or call 1–866–4–USWAGE.

Crane Operators

- **Take training in safe crane operation offered by your employer.**
- **Always use the crane manufacturer's load chart provided for each crane.**

— Do not exceed the crane's lift capacity.

— Do not operate a crane if the load chart is not available.

- **Be sure you know or can calculate the weight of each load.**
- **Never use visual signs of tipping as an indicator of lift capacity.**
- **If necessary, use a spotter to ensure workers are protected from the struck-by hazards of hoisting and swinging loads.**
- **Follow the manufacturer's procedures for proper outrigger deployment to ensure that cranes are properly set up and level with their outrigger pads supported on firm stable surfaces before beginning a lift.**

— Use extreme caution whenever working around trenches, excavations, backfilled locations next to new building construction, sewers, and underground pipes since the weight of the crane can cause these areas to shift or collapse.

— Use specially designed mats, steel plates, timber pads, or concrete rafts under cranes to distribute the load if the ground is too soft, wet, or irregular to provide solid footing. Make timber mats by joining solid timbers or cribbing blocks with long bolts passed through each timber forming a solid mat to prevent individual blocks from rolling out from under the outrigger.

— Make sure blocking placed under outrigger pads is at least 3 times larger than the outrigger pad it is supporting.

— Place blocking so that the entire outrigger pad is supported.

— Make sure blocking is level and at a right angle (90 degree) with the outrigger pad to prevent blocking from slipping out from under the outrigger [Dickie 1999].

- **When multiple lifts are made from one location, such as during duty cycle operations, check the condition of the ground and blocking materials regularly and as often as possible to ensure the crane remains on firm stable ground.**
- **Always check for overhead power lines and other obstructions. Comply with OSHA regulations for safe working distances around power lines.**
- **Avoid hoisting or moving suspended loads over workers and other people within the crane's swing radius.**
- **Barricade the swing radius to keep unauthorized persons from entering areas of pinch points.**
- **Follow a written engineered lift plan for all critical lifts.**
- **If you are under age 18, do not operate a crane or assist in tasks being performed on cranes such as repairing, servicing, assembling, or disassembling the machine.**

— For information about Federal child labor laws, visit www.dol.gov/dol/topic/youthlabor/index.htm or call 1-866-4-USADOL. For links to State labor offices, visit www.ilsa.net or www.youthrules.dol.gov/states.htm or call 1-866-4-USWAGE.

Riggers and Ground Workers Located near Hoisting Operations

- **Be aware that the job site is always changing and be observant of hoisting operations in your work area.**
- **Never work or position yourself directly under a suspended load.**
- **Be observant and watch for signs of problems during each lift.**
- **Always check for overhead power lines and other obstructions. Comply with OSHA regulations for safe working distances around power lines.**
- **Barricade the swing radius to keep unauthorized persons from entering areas of pinch points.**
- **Follow a written engineered lift plan for all critical lifts.**
- **Follow the correct assembly and disassembly procedures when setting up or dismantling a crane. Make sure boom sections are blocked or supported before removing pins. Do not stand under the boom.**
- **If you are under age 16, do not perform any type of construction or manufacturing work. If you are under age 18, do not operate a crane or assist in tasks being performed on cranes such as repairing, servicing, assembling, and disassembling the machine.**

— For information about Federal child labor laws, visit www.dol.gov/dol/topic/youthlabor/index.htm or call 1–866–4–USADOL. For links to State labor offices, visit www.ilsa.net or www.youthrules.dol.gov/states.htm or call 1–866–4–USWAGE.

Crane Rental Companies

- **Make sure cranes are serviced and maintained following manufacturers' specifications.**
- **Make sure each crane is provided with the correct operator's manual as well as load charts, safety decals, maintenance, inspection, and instructional decals, crane signal charts, and other safety information provided by the manufacturer.**
  - — Periodically inspect each crane to ensure warning labels are present and replace as necessary to ensure labels are legible and properly identify the appropriate hazards associated with moving parts, machine guards, pinch points, walkways, handrails, etc.
  - — Replace labels and decals that were damaged or removed during repair work or maintenance (e.g., cleaning, painting, replacement of parts).
- **Make sure that LMI and other safety devices are functioning properly.**

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Please direct any comments, questions, or requests for additional information to the following:

Dr. Nancy A. Stout, Director
Division of Safety Research
National Institute for Occupational Safety and Health
1095 Willowdale Road
Morgantown, WV 26505–2888

Telephone: 304–285–5894; or call
1–800–35–NIOSH (1–800–356–4674)

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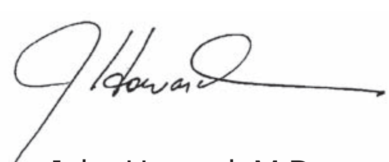

John Howard, M.D.
Director, National Institute for Occupational Safety and Health
Centers for Disease Control and Prevention

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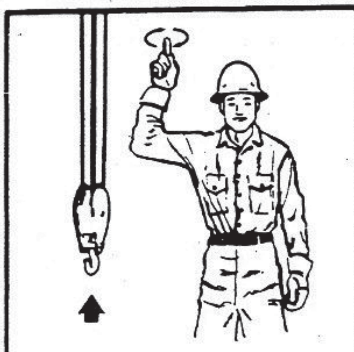
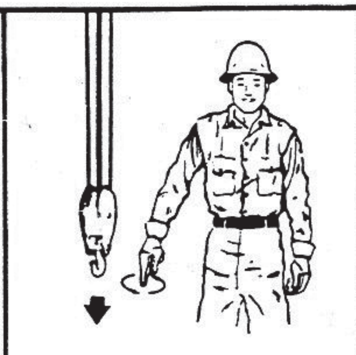
APPENDIX A

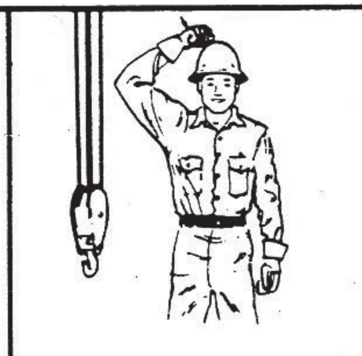
STANDARD CRANE HOISTING HAND SIGNALS*



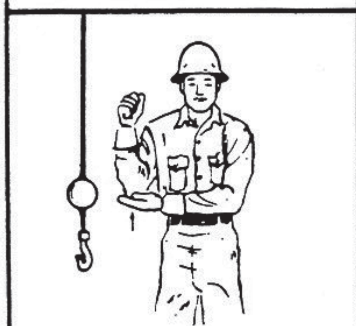
HOIST. With forearm vertical, forefinger pointing up, move hand in small horizontal circle.



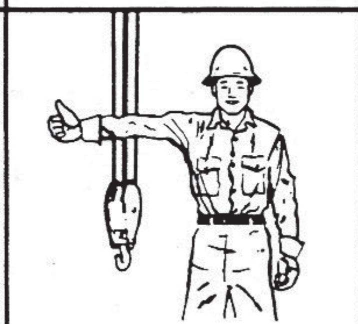
LOWER. With arm extended downward, forefinger pointing down, move hand in small horizontal circle.



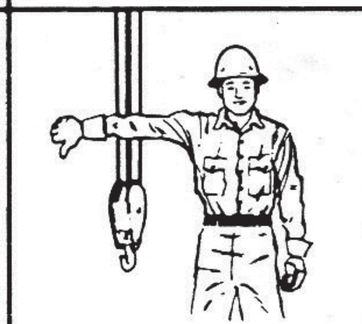
USE MAIN HOIST. Tap fist on head; then use regular signals.



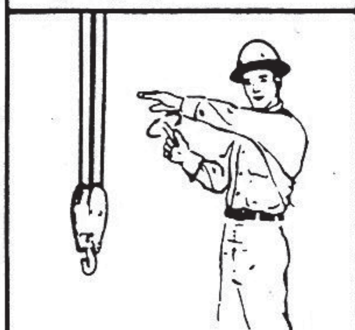
USE WHIPLINE. (Auxiliary Hoist). Tap elbow with one hand; then use regular signals.



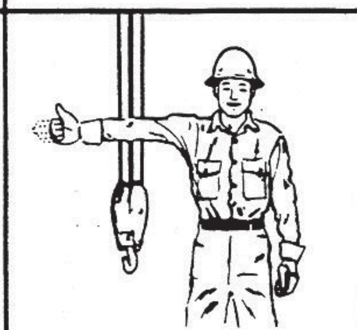
RAISE BOOM. Arm extended, fingers closed, thumb pointing upward.



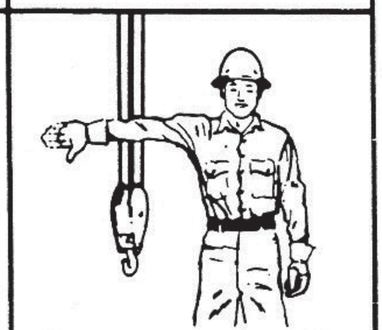
LOWER BOOM. Arm extended, fingers closed, thumb pointing downward.



MOVE SLOWLY. Use one hand to give any motion signal and place other hand motionless in front of hand giving the motion signal. (Hoist slowly shown as example.)



RAISE THE BOOM AND LOWER THE LOAD. With arm extended, thumb pointing up, flex fingers in and out as long as load movement is desired.



LOWER THE BOOM AND RAISE THE LOAD. With arm extended, thumb pointing down, flex fingers in and out as long as load movement is desired.

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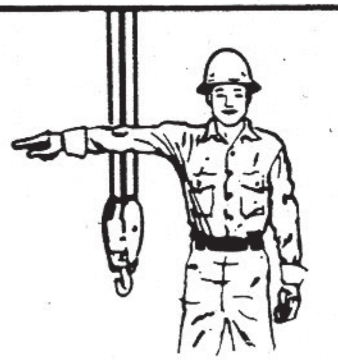
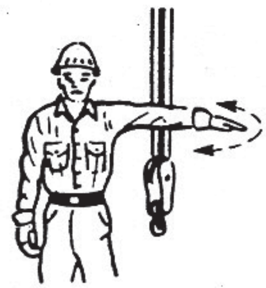
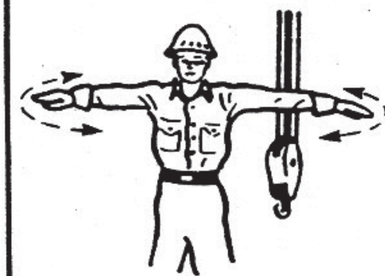


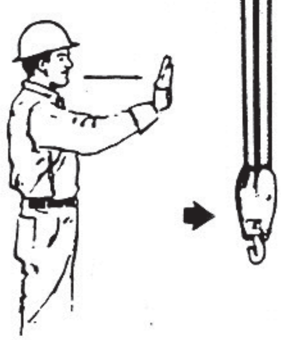
SWING. Arm extended, point with finger in direction of swing of boom.



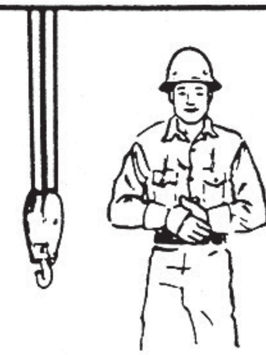
STOP. Arm extended, palm down, move arm back and forth horizontally.



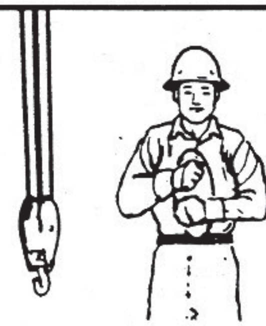
EMERGENCY STOP. Both arms extended, palms down, move arms back and forth horizontally.



TRAVEL. Arm extended forward, hand open and slightly raised, make pushing motion in direction of travel.



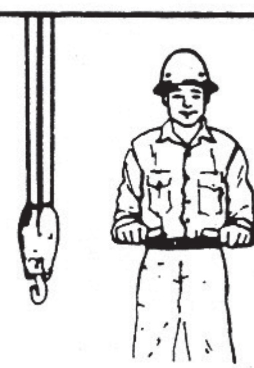
DOG EVERYTHING. Glasp hands in front of body.



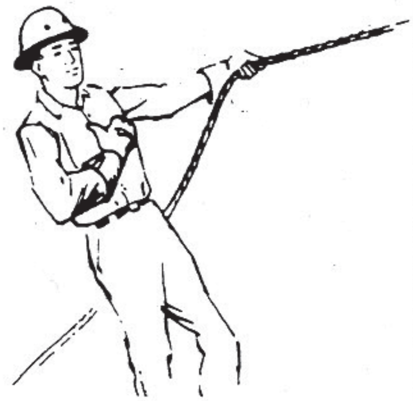
TRAVEL (Both Tracks). Use both fists in front of body, making a circular motion about each other, forward and backward. (For land cranes only.)

TRAVEL. (One Track) Lock the track on side indicated by raised fist. Travel opposite track in direction indicated by circular motion of other fist, rotated vertically in front of body. (For land cranes only.)

EXTEND BOOM (Telescoping Booms). Both fists in front of body with thumbs pointing outward.



RETRACT BOOM (Telescoping Booms). Both fists in front of body with thumbs pointing toward each other.



EXTEND BOOM (Telescoping Boom). One Hand Signal. One fist in front of chest with thumb tapping chest.

RETRACT BOOM (Telescoping Boom). One Hand Signal. One fist in front of chest, thumb pointing outward and heel of fist tapping chest.

NOTES

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