

National Urban Search & Rescue Response System  
Heavy Equipment & Rigging Specialist Training



### Heavy Equipment & Rigging Specialist Training



**Module 2 Unit 3:  
Mobile Crane Basics**

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### Unit Objective

**Describe the types of Mobile Cranes that may be employ at US&R operations and the conditions that effect their efficient use**

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### Enabling Objectives

- Name various types of cranes available and their applicability to US&R tasks
- List requirements for setting up crane
- Describe how to communicate with crane operator
- Describe how to control a load
- Explain why most crane accidents happen

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### Enabling Objectives (continued)

- Describe
  - Capacity basics—stability and tipping axis
  - Ground condition and bearing area issues
  - Strength of crane components
  - How to calculate center of gravity
  - Crane blocks and spreader beam usage
  - Crane accidents and power line issues
  - How a Crane moves the load
  - Crane Signals

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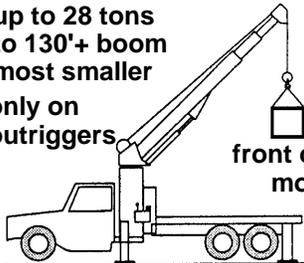
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### Hydraulic Boom Trucks

up to 28 tons  
to 130'+ boom  
most smaller  
only on  
outriggers



front or rear  
mount

Requires little setup time—truck-sized vehicles  
Telescoping or articulating booms

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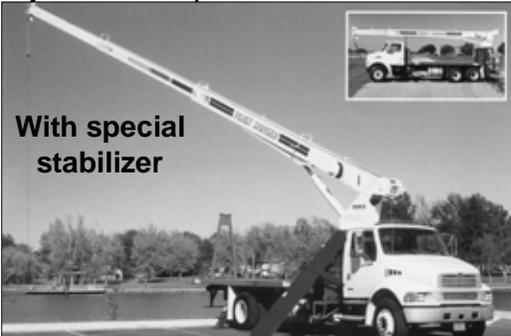
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### Hydro Boom, Front and Rear



With special  
stabilizer

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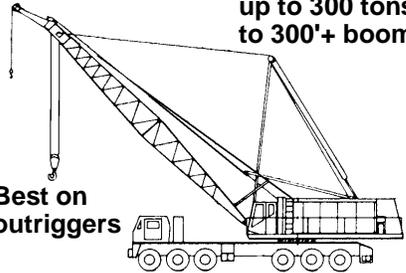
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### Lattice Boom: Truck Crane

up to 300 tons  
to 300'+ boom



**Best on outriggers**

Requires 2 hr min setup time—need setup space  
Lightweight boom allows for larger net loads

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### Crane Setup Requirements

Truck Crane	Lattice Boom	
45 ton	120 ft	crane + 2 trucks
82 ton	140 ft	crane + 2 trucks
125 ton	180 ft	crane + 2 trucks

Need 35-ft wide assembly area  
Need 35 ft x 35 ft operating area

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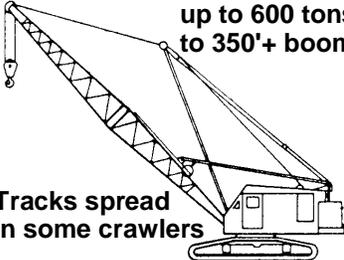
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### Crawler-Mounted Lattice Boom



up to 600 tons  
to 350'+ boom

Tracks spread  
in some crawlers

Requires 4 hr min setup time—need setup space  
Can move around site with only minimum setup

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### Crane Setup Requirements

Crawler Crane	Lattice Boom	
40 ton	120 ft	7 axle transport + 2 trucks
80 ton	140 ft	9 axle transport + 2 trucks
140 ton	180 ft	9 axle transport + 2 trucks

Need 70-ft wide assembly area  
Need 35 ft x 35 ft operating area

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### Crawlers Used in Tilt-Up Construction

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### Assembly of 800T Crawlers



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### Assembly of 800T Crawlers



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### Need place to unload boom trailers



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### 800T in Operation



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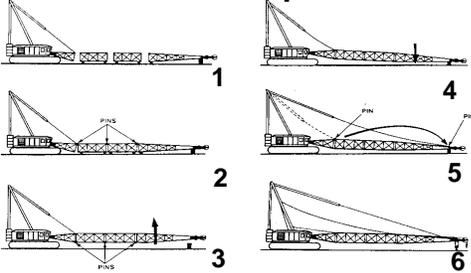
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### Lattice Boom Setup



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Requires time and sufficient space

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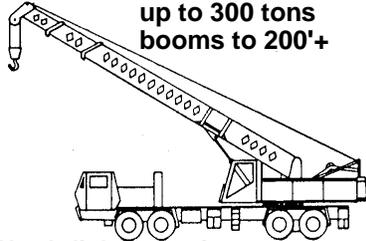
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### Hydraulic Truck Crane Hydraulic/Telescoping Boom



up to 300 tons  
booms to 200'+

Proportional  
Boom and  
Pinned Boom

Best on  
outriggers

Needs little setup time—some extra setup space  
Heavy boom reduces capacity at 70-deg angles

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### Crane Setup Requirements

Truck Crane	Hydro Boom	
Under 50 ton	All booms	crane
Over 50 ton	All booms	crane + 1 truck

Need 35-ft wide assembly area  
Need 35 ft x 35 ft operating area

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### CA-TF-3 Hydro w/Boom Extended (w/o Pinned Section & Jib)



Jib was Removed

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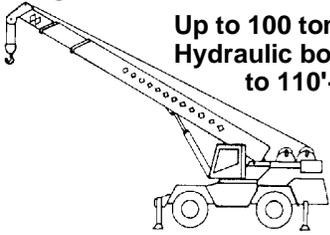
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### Rough Terrain Crane



Up to 100 tons  
Hydraulic booms  
to 110'+

4WD + 4WS  
Best on  
outriggers

Trailer to  
site

Can go across rough terrain to get to load  
Crane needs to be level while lifting  
Can lift and carry—high-angle and level

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### CA TF-3 15-Ton R.T.



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### All-Terrain Crane



up to 300 tons  
booms to 200'+

Have AWD + AWS  
Best on O riggers

Needs to be level  
while lifting

Drives to site—Goes into rough—Very popular  
Same setup and operating area as hydro truck

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### All-Terrain, All-Wheel Drive & Steering



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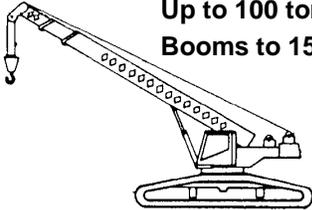
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### Crawler-Mounted Hydraulic/Telescoping Boom

Up to 100 tons  
Booms to 150'



Not many available  
Used in timber industry

Requires little setup time  
Need unloading/setup space  
Move around with no setup, pick, and carry

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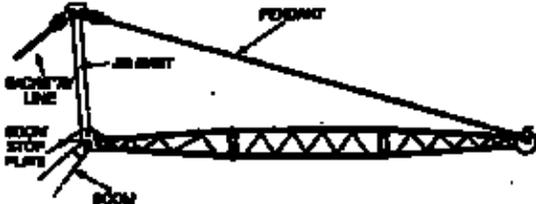
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### Jib for Lattice Boom



Used as straight or offset boom extension  
Usually with single fall of wire rope  
Don't use boom and jib simultaneously  
Add jib weight + when using main boom

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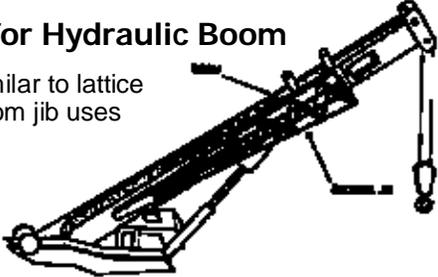
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### Jib for Hydraulic Boom

Similar to lattice boom jib uses



Use only half weight of jib to reduce safe load when jib is in stowed position

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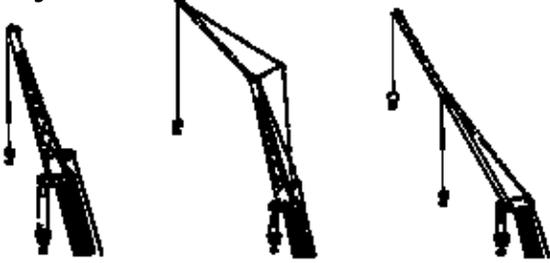
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### Hydraulic Boom Jibs and Extensions



Boom extension      Boom extension + A-frame jib      A-frame jib + telescopic jib

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### Crane Capacity Basics

- Machine weight
- Stability and areas of operation
  - Tipping axis, overturning
  - Experienced operator, LMI
- Strength of crane components
  - Safety Factor varies from 3.0 -3.5 to 1

*Each crane comes with unique capacity chart*

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**Crane Stability—Simple Lever**

Big weight x small dist. = small load x big dist.  
(resisting moment) (load moment)

*Some cranes have load-moment indicators  
(required in CA on cranes over 50T or 200')*

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**Crawler Tipping Axis - Similar All Directions**

Over side      Over rear

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**Carrier Tipping Axis**

Over rear – best      Over side – less

**Over front NOT permitted for most units**

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### Crane Stability

#### Percent of Tipping and Safety Factor (SF)

Crane Type	% of Tipping	SF
Locomotive	85%	1.18
Crawlers	75%	1.33
Mobile on outriggers	85%	1.18
Mobile on tires	75%	1.33
Boom truck on stabilizers	85%	1.18

SF not as large as for anything else  
Load moment indicators warn operators

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### Crawler Bearing Surfaces



Over side      Over corner      Over front

Max ground pressure is Total Weight  
Divided by the contact area of One Crawler

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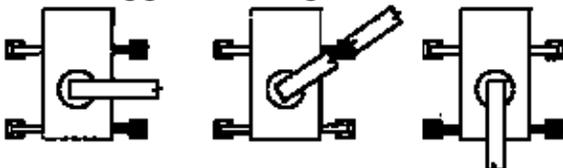
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### Outrigger Bearing Surfaces



Over side      Over corner      Over front

Maximum outrigger force P  
 $P = (W_{\text{machine}} + W_{\text{load}}) / 2$

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### Outrigger Pressures



**Pinned float**



**Added blocking**  
(2 layer solid crib is better)

**150T crane can load 250 k on one outrigger  
on 3' sq float = 28 ksf on 5' sq crib = 10 ksf**

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### Soil Bearing Capacities

Soil Type	Capacity
Medium rock – shale	20 to 30 ksf
Cemented sand and gravel	16 to 20 ksf
Sand and gravel	8 to 16 ksf
Sand	6 to 12 ksf
Silty sand	4 to 8 ksf
Silt	4 to 6 ksf
Loose to firm clay	2 to 4 ksf

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### Outrigger Placing is Important



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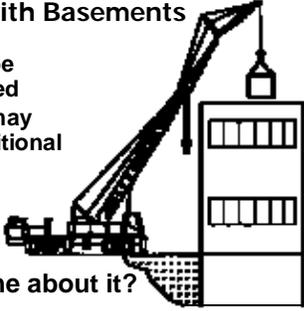
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### Ground Conditions

#### Near Buildings with Basements

- Backfill next to basement may be poorly compacted
- Basement wall may not support additional load from crane



What can be done about it?

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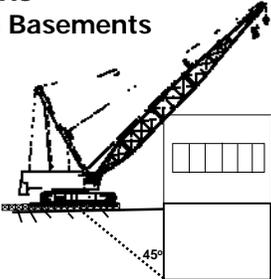
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### Ground Conditions

#### Near Buildings with Basements

- Provide timber mat to reduce pressure
  - Walls adjacent to roadways would normally be designed for some surcharge pressure



45°

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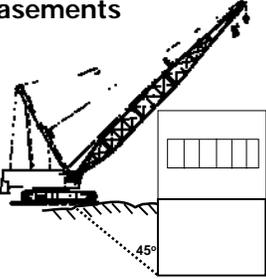
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### Ground Conditions

#### Near Buildings with Basements

- Reduce load by providing setback
  - 45-deg setback will reduce load to insignificant in most soils
  - Crawler spreads load better than outriggers
  - Need longer reach



45°

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**1000T Crane on Mat + Setback**



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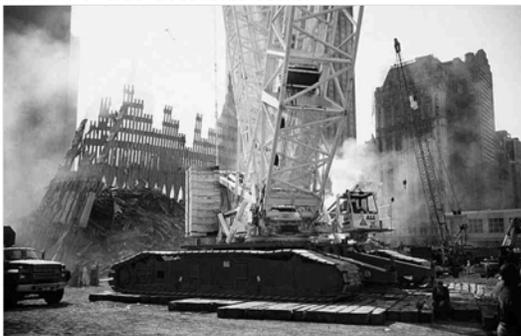
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**800T on Initial Mat**



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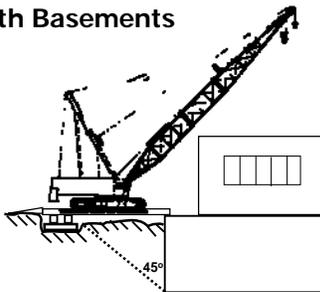
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**Ground Conditions  
Near Buildings with Basements**

- Reduce load by providing bridge
  - Load on soil is placed beyond influence zone
  - Need to design and construct bridge
  - Crawler or outriggers



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### Steel Cribbing Bridge Foot



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### Cribbing Foot to Wall Cap



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### Both Crib Feet Completed



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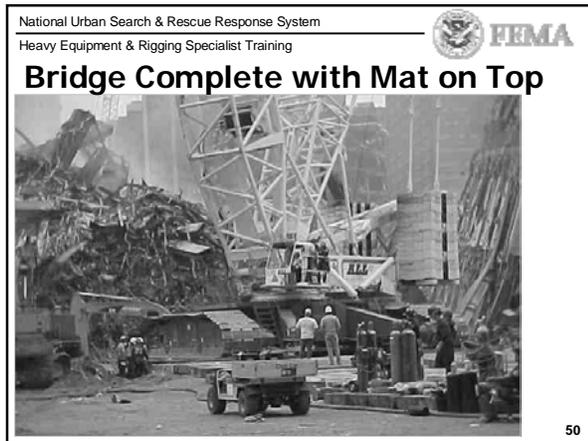
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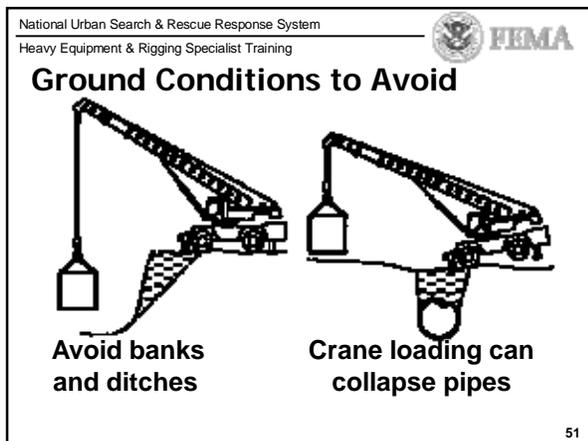
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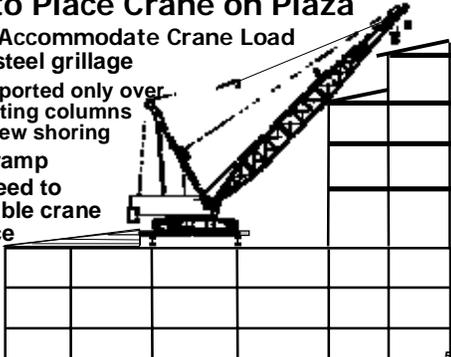
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### Need to Place Crane on Plaza

#### Need to Accommodate Crane Load

- Build steel grillage
  - Supported only over existing columns or new shoring
- Need ramp
- May need to assemble crane in place



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### Constructing Ramp to Grillage



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### Grillage Directly Over Existing Columns



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**Wood Ramp Details**

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**Crane on Completed Grillage**

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**Steel Grillage Details**

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### WTC Site from East Showing Cranes



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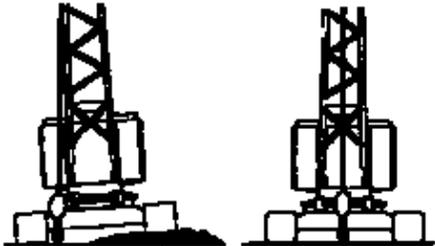
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### Level Crane Base is Critical



Check with levels on crane deck  
or with carpenter's level (4 ft minimum)  
Check using crane block and rotate 90 deg

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### Load Capacity When Crane Out of Level

Boom length and radius	1 deg	2 deg	3 deg
Short boom, min R	10%	20%	30%
Short boom, max R	8%	15%	20%
Long boom, min R	30%	41%	50%
Long boom, max R	5%	10%	15%

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### Side Loading

**Cause of Sudden Failure**  
Can overload one side of boom and/or turntable  
Both lattice and hydraulic booms are affected



**Off-level      Rapid boom swing      Drag load**

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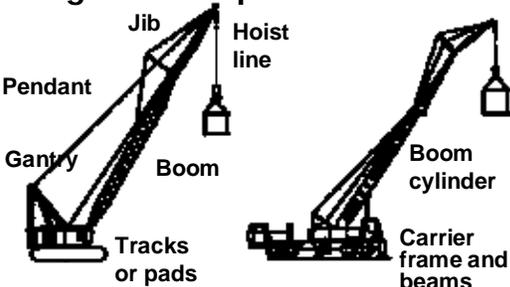
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### Strength of Components



**Many components can fail**

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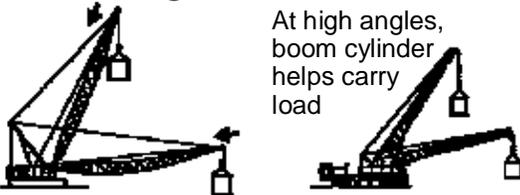
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### Boom Strength Considerations



At high angles, boom cylinder helps carry load

- Lattice boom compression is major cause of failure
- At low angles boom sag adds to buckling problem
- Hydraulic booms have problem at low angles because of bending

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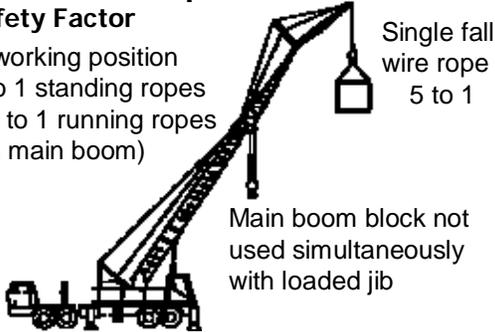
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### Crane Wire Rope Safety Factor

In working position  
3 to 1 standing ropes  
3½ to 1 running ropes  
(on main boom)



Single fall wire rope 5 to 1

Main boom block not used simultaneously with loaded jib

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### Crane Blocks and Multi-Part Line

- Blocks used when loads exceed SWL of single wire rope
  - Line with single rope is faster
  - Multi-part line, multiplies SWL, is slower, but gain greater control
- 3% to 5% friction generated at blocks
  - SWL of multi-part line system is not just SWL of one line times the number of parts

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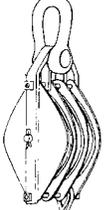
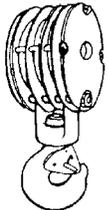
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### Blocks: Crane and Other



**Crane block**  
heavy to aid unloaded down haul

**Wire rope block**  
lighter weight and not as subject to abuse

**Snatch block**  
used to change direction of line

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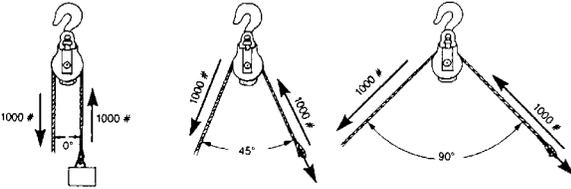
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### Forces on Snatch Blocks

2000 lb	1840 lb	1410 lb
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Based on a load of 1000 lb

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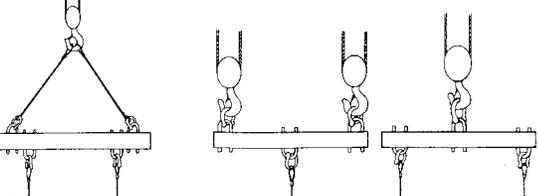
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### Spreader and Equalizer Beams



**Spreader used to lift long loads**  
Limit tipping, sliding, and bending + low sling angles

**Equalizer used in dual hoist lines & tandem lifts**  
Also to equalize load on sling legs

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### Spreader and Equalizer Beams

Equalizer used in dual hoist + spreaders and sling system to provide equal lift on TU Inserts

Conc panel wt = 110k  
Conc panel size = 39' x 33'



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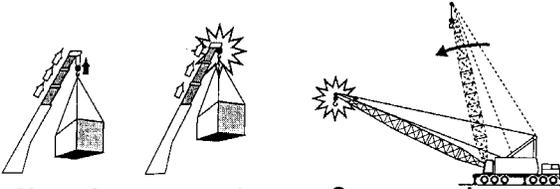
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### Two Blocking

Hook block is pulled into boom tip sheaves



Most often occurs when hydraulic boom extended      Can occur when lattice boom lowered

**Anti-two block device – solenoid/limit switch**

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### Two-Blocking Device



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### Crane Accident Summary

(from I.U.O.E. , Local #18)

- Support failure = 32%
- Failure to use outrigger = 23%
- Operator error = 33%
- Structural failure = 11%
- High wind = 2%

**Over half relate to crane setup**

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### Clearance Guide for Operating Near Electric Power Lines

Voltage	Minimum Clearance
To 50 kv	10 ft
51 to 200 kv	15 ft
201 to 350 kv	20 ft
351 to 500 kv	25 ft
501 to 750 kv	35 ft
751 to 1000 kv	45 ft

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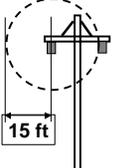
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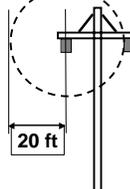
### Limit of Approach to Power Lines

Less than  
125,000 v



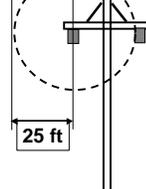
15 ft

125,000 to  
250,000 v



20 ft

More than  
250,000 v



25 ft

If crane component or the load can swing within limit, a signal person must be positioned to observe the approach.

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### Mobile Crane Fatalities (Construction Industry 1969-89)

■ Power lines	=	48	44%
■ Rigging	=	16	15%
■ Load handling	=	15	14%
■ Operator error	=	8	7%
■ Overload	=	8	7%
■ Dismantling boom	=	5	5%
■ Wire rope failure	=	5	5%
■ Miscellaneous	=	5	5%

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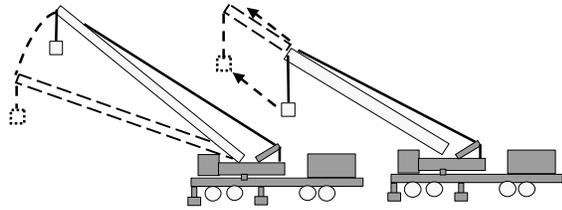
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### Crane Signals

How does the load move Vertically?



Boom - Up or Down  
Load moves in an Arc

Boom - Out or In  
Load parallels Boom

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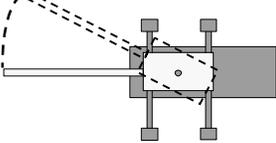
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### Crane Signals

How does the load move Horizontally?



Swing Boom – Right or Left – about Center Pin  
Load moves in an Arc, not Right or Left

**To give coherent signals, you need to understand this!**

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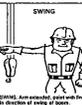
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### CRANE SIGNALS

ALWAYS STAND IN CLEAR VIEW OF YOUR CRANE HOIST ENGINEER  
BE SURE TO STAY A SAFE DISTANCE FROM HOOK, BLOCK OR BOOM

Developed by SPECIALIZED CARRIERS & RIGGING ASSOCIATION  
In accordance with the American National Standards Institute

<p><b>USE MAIN HOIST</b></p>  <p>USE MAIN HOIST: Top fist on head, then left hand down.</p>	<p><b>USE WHIP LINE</b></p>  <p>USE WHIP LINE: Secondary hoist Top fist on head, then left hand up.</p>	<p><b>RAISE BOOM</b></p>  <p>RAISE BOOM: Arm extended, fingers closed, thumb pointing upward.</p>	<p><b>LOWER BOOM</b></p>  <p>LOWER BOOM: Arm extended, fingers closed, thumb pointing downward.</p>
<p><b>HOIST</b></p>  <p>HOIST: With one extended forearm, hand open, pointing down, thumb held in palm, fingers closed.</p>	<p><b>LOWER</b></p>  <p>LOWER: With one extended forearm, hand open, pointing down, thumb held in palm, fingers closed.</p>	<p><b>MOVE SLOWLY</b></p>  <p>MOVE SLOWLY: This one hand is up and the other is down. Keep hand in position in front of head when the hoist is up. (Do not touch hoist.)</p>	<p><b>RAISE THE BOOM AND LOWER THE LOAD</b></p>  <p>RAISE THE BOOM AND LOWER THE LOAD: RAISE THE BOOM: With one extended forearm, hand open, pointing down, thumb held in palm, fingers closed. Then hoist up and out as the boom is raised to desired position.</p>
<p><b>RAISE THE BOOM AND RAISE THE LOAD</b></p>  <p>LOWER THE BOOM AND RAISE THE LOAD: With one extended forearm, hand open, pointing down, thumb held in palm, fingers closed. Then hoist up and out as the boom is raised to desired position.</p>	<p><b>SWING</b></p>  <p>SWING: Arm extended, palm with finger in direction of swing of boom.</p>		

Hand signals should be found on the side of every crane cab.

They should conform to the NCCCO Standard

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### Voice Crane Signal Examples

- **Swing right 50ft, 25ft, 15ft, 10ft, 5ft, 2ft, swing stop**
- **Lower load 100ft, 50ft, 25ft, 5ft, lower stop**
- **Hoist load slow, slow, keep hoisting slow, hoist stop**

**Signal person will give swing commands from the operator's perspective**

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### Review—Enabling Objectives

- **Name various types of cranes available and their applicability to US&R tasks**
- **List requirements for setting up crane**
  - Capacity basics—stability and tipping axis
  - Ground condition and bearing area issues
  - Strength of crane components
  - Crane accidents and power line issues
- **Describe how to communicate with crane operator - hand & voice**

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### Evaluation

**Please complete the evaluation form for Module 2 Unit 3: Mobile Crane Basics**

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**STUDENT MANUAL**  
**HEAVY EQUIPMENT & RIGGING SPECIALIST TRAINING**  
**MODULE 2**  
**UNIT 3: MOBILE CRANE BASICS**

**Unit Objective**

Upon completion of this unit, you will be able to describe the types of mobile cranes that US&R operations may employ and the conditions that affect their efficient use.

**Enabling Objectives**

You will:

- Name the various types of cranes that would be available and their applicability for accomplishing various tasks during a US&R incident;
- List the requirements for setting up a crane at the US&R site;
- Describe how to communicate with the crane operator;
- Describe how to control a load;
- Explain why most crane accidents happen; and
- Describe:
  - ◆ Capacity basics—crane stability and tipping axis,
  - ◆ Ground condition and bearing area issues,
  - ◆ Strength of crane components,
  - ◆ Crane blocks and spreader beam usage,
  - ◆ Crane accident and power line issues, and
  - ◆ Crane hand and voice signals.





## **I. Objectives**

### **Unit Objective**

Upon completion of this unit, you will be able to describe the types of mobile cranes that US&R operations may employ and the conditions that affect their efficient use.

### **Enabling Objectives**

You will:

- Name the various types of cranes that would be available and their applicability for accomplishing various tasks during a US&R incident;
- List the requirements for setting up a crane at the US&R site;
- Describe how to communicate with the crane operator;
- Describe how to control a load;
- Explain why most crane accidents happen; and
- Describe:
  - ◆ Capacity basics—crane stability and tipping axis,
  - ◆ Ground condition and bearing area issues,
  - ◆ Strength of crane components,
  - ◆ How to calculate the center of gravity—odd objects and weight,
  - ◆ Crane blocks and spreader beam usage,
  - ◆ Crane accident and power line issues, and
  - ◆ Crane Hand and Verbal Signals.

## **II. Crane Types, Sizes, and Attributes**

### **Boom Trucks**

Boom trucks are mounted on commercial truck chassis that have been strengthened to accept a crane that may be configured with a hydraulic telescoping or articulating boom.

The boom's anchor point may be located at either the front or rear end of the truck bed.

Rated capacities range up to 26 tons, but 100 percent of capacity is only available at very short distance (5 feet or so) from the center of rotation. The capacity drops to about 25 percent at the 20-ft load radius.

Outriggers or stabilizers must be deployed in order to lift any substantial load.

- Articulating (knuckle) boom trucks are primarily used for loading and unloading materials from a truck bed at minimum radius.



- Those fitted with hydraulic booms are often used for unloading and erecting lighter construction components such as roof trusses, steel framing, pipe, etc.
- Hydraulic booms are available in up to four sections and in lengths of up to 100 feet that can be extended to 140 feet with the use of jibs.
- However, the capacity of a 28-ton, hydraulic boom truck with long boom and jib is only 1,350 pounds (2 percent) at an 80-ft radius.
- Most of these cranes have a rating of less than 10 tons with booms in the range of 50 feet.
- They should have Anti-Two Block (ATB) devices, and larger capacity models should have Load Moment Indicators (LMI).
- Qualified operators are required for safe (and legal) operation of these as well as all other cranes.

### **Lattice Boom Truck Cranes**

Lattice boom truck cranes feature a relatively light, trussed boom consisting of four longitudinal chords (one at each corner) made from round, square, or angled, high-strength steel members that are diagonally trussed with smaller members of the same shape. These cranes are mounted on carriers that are solely designed for crane service.

As a group, they are the oldest cranes in use, although those with less than 60-ton capacity are being slowly phased out.

Except for some very new models, lattice cranes take significant time and require a lot of space to be assembled. As many as six trucks may be required to transport the crane, including boom sections and counterweights. Assembly can take from 2 to 8 hours, depending on the availability of an assisting crane.

The rated capacity for cranes may be as high as 300 tons, with those in the range from 100 to 150 tons being quite common. Areas of operation (discussed in next section) include over rear, over side, and over front. Booms over 100 feet are common, with maximum lengths, including jib extensions, being in the range of 300 feet.

As an example the capacity of a 150-ton, Link Belt HC-238H is 150 tons at a radius of 10 feet.

- At a radius of 40 feet, this crane has a capacity of 39 tons (26 percent).
- It drops to 16 tons (11 percent) at an 80-ft radius.
- Capacity is only 2 tons (1.3 percent) at a 200-ft radius.
- These capacities require the deployment of outriggers and assume a level and stable carrier.
- If the crane operates without outriggers (on rubber), these capacities drop to 55, 18, 7, and 0 tons respectively.

In summary, these cranes are relatively efficient and versatile and have far-reaching lifting capabilities but require time and space to assemble.



## **Crawler-Mounted Lattice Boom Cranes**

Crawler-mounted lattice boom cranes are rugged cranes consisting of lattice boom upper works placed on a crawler carrier. They are designed for the extreme duty associated with the crawler and are available in capacities of up to 600 tons and booms over 300 feet.

Crawlers normally need to be moved to the site by trailer and then set up similar to any lattice boom crane. When the crane arrives at the site completely broken down, assembly can include lifting the crane house onto the carriage and installing the counterweight and boom.

Once the crawler cranes are assembled, they can move around the site at 1 or 2 mph, and can make moderate lifts with minimum setup (leveling, rigging, etc.). They do not have outriggers to set, although some have retractable tracks. For critical lifts or in soft soils, wood, or steel, bearing mats may be required.

The Manitowoc Model 777 has a 175-ton rated capacity at a radius of 13 feet.

- 54-ton (31 percent) capacity at a 40-ft radius
- 20.5-ton (12 percent) capacity at an 80-ft radius
- 2.4-ton (1.4 percent) at a 200-ft radius

## **Lattice Boom Setup**

The lattice boom comes in many sections that are interconnected with large pins. There are base and tip sections separated by a number of 10- to 20-ft interior sections.

Although most lattice boom cranes can assemble their own booms, a small auxiliary crane, even a boom truck, can greatly speed the process. Boom assembly normally proceeds by first laying out the sections in the order specified. Sections are placed on wood blocking and pulled together to align the upper pin holes. The upper pins are set, using cotter pins as retainers. Pins are normally installed so that they can be removed from the outside (cotter pin end out). After the top pins are set, the assembly is boomed up slightly in order to install the bottom pins when they become aligned. Accidents can easily happen during this part of the process, so only experienced assemblers should be employed.

To complete assembly, the pendant levers are properly positioned, and the interconnected boom is slowly raised into lifting position. In some cases, an auxiliary crane may be required to initially raise the boom.

Reversing the process dismantles the lattice boom. The lower pins are removed after the boom is lowered, blocked at the end, and the pendant line moved to the top of the base section. The boom is then blocked at each end of each section so that the upper pins can be removed. Again, great care should be taken when removing pins. Use a long bar with access outside the boom.



## **Counterweight Installation**

Many cranes, including larger hydraulic boom types, require the installation of counterweights. The parent crane or a smaller auxiliary crane can do this lifting job.

If a crane lifts its own counterweights, it must be configured with at least its basic boom sections, be nearly level on firm ground, and have a minimum of four parts of line reeved on the boom.

## **Hydraulic Truck Cranes**

These cranes are designed to move swiftly over the highway on specially designed carriers. Depending on Gross Vehicle Weight (GVW) limitations, some components (outriggers and counterweights) may need to be transported by separate trucks and assembled at the job site.

The setup time is greatly reduced over that required for most lattice boom cranes since the telescoping, hydraulic boom is transported as part of the crane/carrier assembly.

Hydraulic truck cranes are subdivided into two types based on their type of boom tip section: full-power and pinned.

- Full-power boom type: all boom sections (including the tip) extend proportionally as the boom is extended.
- Pinned booms: the tip section is either fully retracted or fully extended at all times regardless of total boom length.

In older hydraulic boom cranes, all boom sections would extend sequentially (all out, all out, all out). New designs require that all boom sections move proportionally, which is a stronger/better assembly.

The most common number of boom sections is three or four, but new computer-controlled hydro cranes have as many as six sections.

The Grove TMS870, 70-ton capacity hydro truck crane has a 70-ton capacity at a 10-ft radius.

- 13-ton capacity (20 percent) at a 40-ft radius and 3.8-ton capacity (6 percent) at an 80-ft radius

The Link-Belt HTC8665, 65-ton capacity hydro truck crane has 61.5-ton capacity (95 percent) at a 10-ft radius.

- 8.8-ton capacity (13 percent) at a 40-ft radius and 2-ton capacity (3 percent) at an 80-ft radius

These truck cranes may also be operated on rubber, but at significantly reduced capacity.



### Rough Terrain Cranes

These hydraulic boom cranes are designed to move around the job site, but normally travel by trailer over the highway. They are not designed to lift or carry load in rough terrain but may lift and slowly carry as long as they remain within 1 percent of level (1 foot in 100 feet).

They come in at least two configurations: fixed or rotating cab.

They are normally configured with 2- and 4-wheel drive as well as 2- and 4-wheel steering and can be operated either on outriggers or on rubber with appropriate capacities. The capacity of this type of crane can be as much as 100 tons, and the booms can extend over 150 feet with appropriate extensions.

Many of these cranes are available and are in common use at construction sites. These cranes may be fitted with various types of boom extensions, which will be discussed later. A common nickname for a rough terrain crane is a *cherry picker*.

The Link Belt RTC8065 (65-ton) Hydro Rough Terrain Crane has a 65-ton capacity at a 10-ft radius (outriggers fully extended).

- 15-ton (23 percent) capacity at a 40-ft radius
- 4-ton (6 percent) capacity at an 80-ft radius
- These capacities drop to 36 tons at 10 feet and 6 tons at 40 feet when the crane is operated on rubber in a stationary position or at 1 mph in “pick and carry” mode.

### All-Terrain Hydraulic Boom Truck Cranes

These increasingly popular cranes are a blend of both the rough terrain and hydro truck crane. They have a lower center of gravity and are equipped with highway tires, improved suspension, and all-wheel drive capability. This equipment allows them to be self-transported from job to job at up to 55 mph. Once confronted with a rough job site, they can use multi-wheel steering and all-wheel drive to quickly position themselves in order to lift the appropriate load. They are available with capacities up to 440 tons and with boom lengths over 200 feet when fitted with extensions.

The Grove GMK5175 (175 ton) All Terrain Hydraulic Crane has a 175-ton capacity on outriggers at a 10-ft radius.

- 48-tons (27 percent) capacity at a 40-ft radius
- 17-ton (10 percent) capacity at an 80-ft radius
- 1.8-ton (1 percent) capacity at a 200-ft radius
- These values are with outriggers fully extended with maximum counterweight (50 tons), and are appropriate for lifting throughout the 360-degree swing of the boom.
- No on-rubber capacities are listed.



### **Crawler-Mounted Hydraulic Boom Cranes**

There are fewer numbers of crawler-mounted cranes than the others mentioned. They combine the rapid setup of the hydraulic boom with the stability and mobility of a crawler crane. They are available with boom lengths over 150 feet and capacities to 100 tons or so. They are used in the logging industry, and some are equipped with permanently lubricated rubber tracks.

#### **Jibs and Boom Extensions**

Jib and boom extensions are used to extend the reach of both lattice and hydraulic telescoping booms. Most, but not all, boom extensions are lattice types.

In the case of a lattice boom crane, the jib should be erected during the original boom setup. This type of jib has many parts, such as jib mast, wrap-a-round pendant, backstay line, and lattice jib boom (in one or more sections).

The jib is often, not always, operated with a single fall of wire rope and usually not operated simultaneously with the main boom block.

The jib weight needs to be accounted for in computing the capacity of the main boom/main block. Since the jib center of gravity is beyond the main boom tip, its effective weight may be as much as twice its actual weight. Most load charts will give values for this load (that reduces the net lifting capacity).

On hydraulic boom cranes, boom extensions may be of several types.

- They may be stowed on the side of the base section when not in use (swing away jib or extension).
- Since the center of gravity is closer to the axis of rotation when the booms are stowed than when erected, they have an effective load of less than their actual weight.

Boom extensions and jibs allow a crane a much greater reach, but also significantly reduce its lifting capacity when compared with a main boom of the same length. They may be offset (angled from straight line of main boom axis) at specific angles, such as 1 degree, 17 degrees, and 30 degrees.

Their capacity decreases as the angle that their axis makes with the horizontal decreases, regardless of whether the boom angle changes or the jib to boom angle changes. As the jib angle becomes less, the force in the pendant increases. (When this angle is near zero, the pendant needs to provide most of the vertical resistance to the jib tip.)

### **III. Crane Capacity Basics**

A crane's lifting capacity is based on:

- Machine weight,
- Stability and areas of operation, and
- The strength of its components.



### Crane Stability

The modern crane may be a complicated, computer-aided machine, but it operates as a first-class lever.

Its stability is determined with a basic equation that is useful in analyzing most structures. The tendency to tip the structure over (**overturning moment**) must be exceeded by its resistance to overturning (**resisting moment**).

The machine weight plus its counterweight is centered (machine center of gravity) a relatively short distance from the tipping axis (center of outriggers, center of crawler tracks, or center of tires). The product of this large weight times the short distance provides the **resisting moment**. The weights of all the crane's components from the boom tip to the counterweight are normally considered as part of this weight.

The product of the weight (force, load) of what is to be lifted by the crane plus all other objects below the boom tip (block, rigging, jib, etc.) times the distance from the center of this load to the tipping axis is the **overturning moment**.

### Tipping Axis

The distance from machine center of gravity to tipping axis varies depending on the type of carrier and the direction of the axis of boom relative to axis of carrier base.

For crawlers, the resisting moment is similar when lifting over side to lifting over rear, and most of these rugged cranes have the same lifting capacity in all directions (360-degree rating).

Truck cranes normally have outriggers and are configured such that there is greater tipping resistance when lifting over the rear. (Areas of operation will be discussed in next section.)

- Lifting over the side may be nearly as stable as over the rear, but lifting over the front may be severely limited unless the crane is fitted with a front stabilizer (outrigger).
- When operating a truck crane without outriggers (on rubber), lifting and lift and carry are normally only permitted over the rear.

Rough terrain cranes are normally configured so that they can pick and carry on rubber, only over the front. With outriggers extended, they may have similar tipping resistance in all directions, but usually their capacity will be greatest over front.

### Crane Stability + Safety Factor (SF)

Cranes are rated such that the overturning moment induced by the maximum permitted load can be as much as 85 percent of the moment that will tip over the crane (tipping moment, overturning moment).

This means that the safety factor for tipping a crane can be as low as 1.18. This is smaller than that of any component in the lifting system, and is justified on the basis of the following:

- Special precautions are taken when the load to be lifted is greater than 75 percent of the maximum load as defined by the load chart. Use trial lifts and employ extra spotters.



- The Load Moment Indicator (LMI) device may be used to accurately measure the tipping potential.
- An experienced crane operator may be able to adjust the position of the load quickly if overturning is imminent.

This close tolerance for tipping requires that all who employ cranes exercise great care in determining all the factors that affect the lift when operating within 75 percent of capacity.

## **IV. Ground Conditions and Bearing Areas**

### **Bearing Surfaces and Pressures**

One of the assumptions of safe and predictable crane operations is that the crane base is firmly supported.

The tracks of a **crawler carrier** contact the ground with broad surfaces. Maximum stress occurs at edges, but a greater area will be mobilized (much like a continuous building foundation) if there is a small amount of yielding of the soil bearing material.

In addition, the maximum bearing pressures occur over the smallest area when lifting over a diagonal corner. Avoid lifting critical loads (over 75 percent of capacity) when the boom is aligned in this position, or if the load is to be swung through this position.

The bearing surface can be increased for critical lifts or when lifting on softer soils by installing large bearing mats. Mats are usually constructed using 8 x 8 to 12 x 12 timbers that are bolted together with threaded rods and/or with surface layers of plywood. Mats are approximately five feet wide and are placed so that the timbers are aligned perpendicular to the tracks. A set of mats, with appropriate length, is normally supplied with the crane, and, of course, require adequate time to be installed.

**Truck and rough terrain cranes** deliver their bearing loads to the ground through outriggers.

- The contact area of an outrigger is small (pontoons/floats are 2 to 3 feet in diameter).
- They are designed to induce a maximum pressure of over 200 pounds per square inch (29 ksf) on the ground or pavement surface.
- Blocking, cribbing, or prefabricated, bearing mats should be placed under the floats to increase the bearing area.
- A 5-ft square, solid wood crib has 3½ times the area of a 3-ft diameter float.

Most prefabricated bearing mats are constructed with larger timbers aligned in one direction and connected by steel rods placed through all the timbers.

- Because of shrinkage in wood, this configuration does not spread the load evenly in each direction.
- A two-level, solid wood crib would better spread the load, but most crane operators are trained to avoid built-up blocking due to questions about stability.



## **Soil Bearing Capacities**

Only rock or well-cemented sand and gravel have a capacity near the 20 ksf to 30 ksf pressure range, which can be delivered by un-blocked outriggers.

Cracked concrete or asphalt pavements are only as strong as the sub-grade beneath them, although they may spread the load a little.

One should use cribbing or bearing mats under all outriggers to assure a stable crane base. It should be noted that even in the case of using a 5-ft square crib under a 3-ft diameter outrigger float that is loaded at maximum crane capacity, the pressure delivered to the ground is in the 10 ksf range.

For larger crawler cranes, it may be necessary to construct heavy mats from 8 x 8 to 12 x 12 timbers.

- The timbers would be configured with their long direction placed perpendicular to the crawler tracks.
- The timbers would extend about 5 times the timber thickness beyond the tracks on each side of the crane.
- The timbers are normally bolted together in groups of 4 or 5.

## **Ground Conditions to Avoid**

There are several common conditions in which soils could be unable to provide stable support for the high pressures imposed by a crane. These conditions include:

- Locations adjacent to basements and other underground structures and
- Locations directly over buried pipes or other buried structures, such as subways, and adjacent to the edge of a bank or open trench.

In both cases, the problem is made worse due to the probability of inadequate backfill compaction. Cranes with outriggers are more difficult to deal with in these conditions, since they produce high, isolated loads. Crawler cranes tend to spread out their loads better.

For the case in which a crane must be placed near a basement, there are several methods to mitigate the problem.

- **Reduce the bearing pressure** by building large timber mats.
  - ◆ Most basement walls adjacent to streets are designed for a “surcharge load” that allows for normal truck traffic, and if the pressure from the crane can be reduced to the surcharge level, damage to the wall should be avoided.
  - ◆ However, one would need to determine the basis of design for the wall in question.
- Set back the crane from the wall.
  - ◆ To reduce the crane’s effect on the wall entirely, one would need to make the setback a distance as deep as the basement.



- ◆ If the wall has been designed for a significant “surcharge load,” one may be able to reduce the setback to about half of the basement’s depth.
- Build a bridge adjacent to the basement
  - ◆ The bridge would span from a cribbing/footing placed at least the depth of the basement away from the wall to on top of the wall.
  - ◆ The bridge would need to be designed properly so as to support the crane, using large steel or timber members.

When a crane needs to be placed near the edge of a bank or ditch, its outriggers should be placed so that they are spaced a reasonable distance away from the edge. This distance should be at least 1½ times the height of the ditch/bank and be measured from the vertical face of the ditch (or what would have been the vertical face).

Buried pipes can be collapsed by the high pressures applied by a crane and are especially vulnerable when covered with a poorly consolidated backfill. One can sometimes “read” this condition in asphalt pavements and possibly avoid it or otherwise provide mitigation like large mats. Buried pipes will be found adjacent to most buildings and most often cannot be avoided.

### **Placing Cranes On and Within Structures**

In some cases, cranes may need to be placed on a plaza that surrounds a building or within the building.

- Depending on the floor design load, smaller cranes may be safely supported on a concrete floor structure.
- One would need to obtain the structural drawings and calculations or receive approval from the engineer who designed the building.
- In most cases, only small cranes would be able to be safely supported.

For the cases in which the crane cannot be supported on a floor structure, it may be possible to design a grillage, or two-way beam system, that is supported directly over the structure’s columns.

- This assumes that the columns would have adequate capacity to support the additional load of the crane.
- As an alternative, one may install shoring to support the crane load, but this would require great care.
- The shoring would have to be well-supported and tight to the floor structure so that the load would be transferred to the shoring instead of the floor structure.



The actual placing of the crane on the structure must be carefully planned.

- The crane may need to be erected on the structure using another crane, especially one with heavy counterweights.
- A ramp may need to be used to drive onto the structure.
  - ◆ The ramp must be constructed so that when the crane passes over it, the supporting structure is not overloaded.
  - ◆ If the overload of the ramp supporting structure cannot be avoided, it would need to be shored.

### **Level Crane Base and Side Loading**

The assumption of all crane capacity charts is that the base is not only firmly supported on a stable surface but is level. Even being 1 percent (1/8 inch in one foot) out of level can reduce the lifting capacity 30 percent for a crane using its longest boom when lifting at a minimum radius.

- The reason for the reduction is that the boom and other parts of the crane will be loaded unevenly.
- Lattice booms are especially vulnerable to uneven loading since most of the load could be concentrated in only one or two of the boom chords (boom corner members). An overloaded boom chord can cause a sudden compression buckling failure, leading to boom collapse.

Most cranes come with leveling devices on the base deck; however, a very accurate (but time consuming) way to check level is to use the suspended crane block to check level in each direction.

**Side loading** produces the same reductions in capacity and can be caused by:

- Too rapid a swing rate, causing the load to move out from directly below the boom tip, which causes a side load at the boom tip based on the angle that the wire rope line varies from vertical.
- Picking up load that is not centered on boom. In this case, the line will, again, initially be off vertical until the load moves to its normal position directly below the boom tip.



## **V. Strength of Crane Components**

### **Structural Failure**

Even though crane tipping (overturning moment) governs the capacity of a crane for the majority of lifts, there are some situations in which the capacity would be determined by the strength of one or more crane components.

Crane load charts normally indicate the capacities that are governed by “strength,” with shading showing these values above a heavy line or by adding an asterisk.

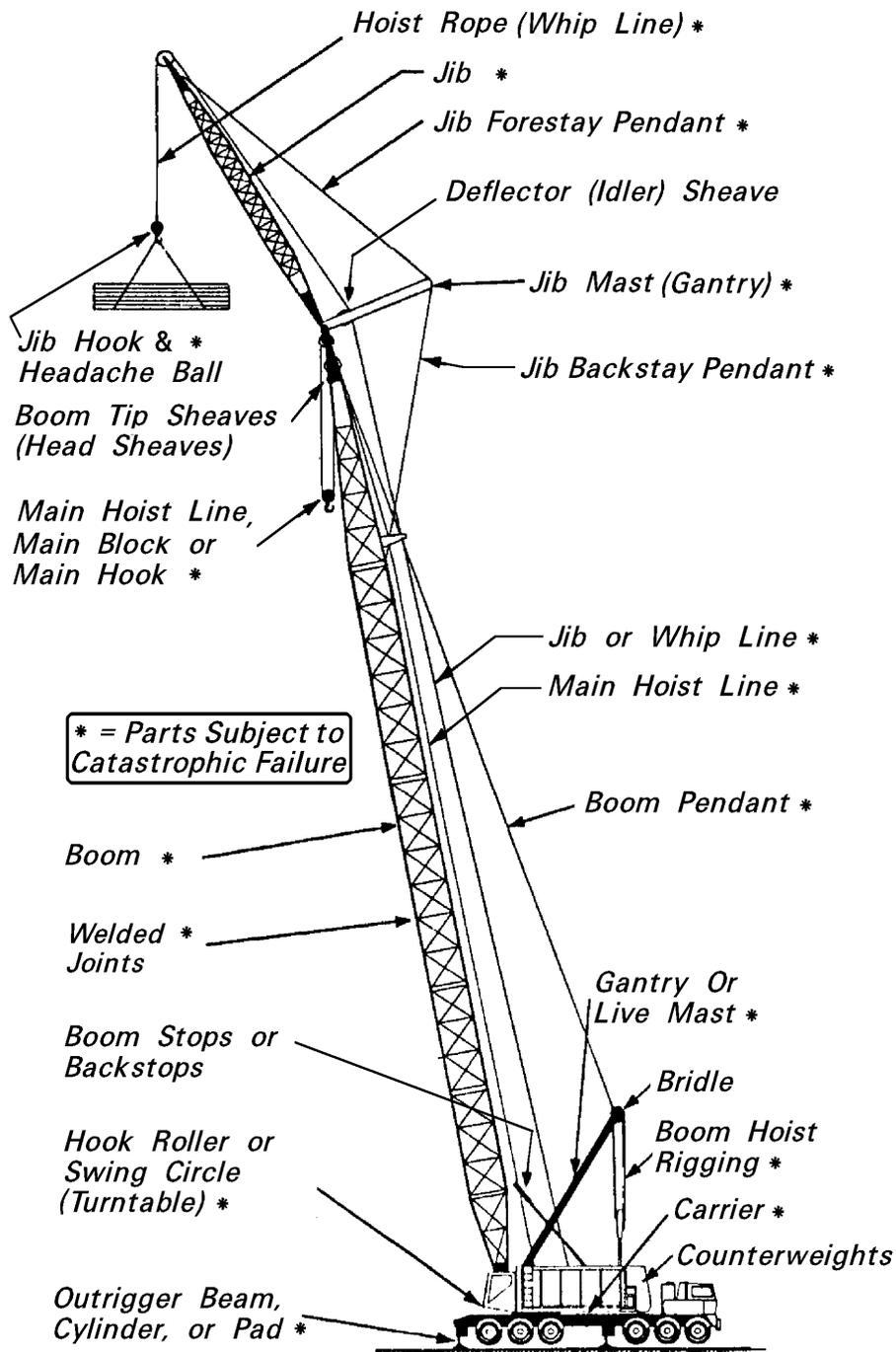
- This condition usually occurs when the main boom is at a relatively high angle (greater than 60 degrees) since the radius is relatively small, thereby allowing a relatively high load capacity.
- The controlling component will probably be boom compression strength for a lattice boom crane; however, for hydraulic booms at high angles, the boom cylinders may limit capacity since they carry part of the load.

Since the most modern cranes are very complicated machines that have been designed for maximum efficiency, there are many components that could limit capacity.

When jibs are attached, their strength will usually control the amount of allowable lift. Other items that could control capacity are:

- Boom compression — especially lattice type,
- Boom bending—especially hydraulic at low angles,
- Pendant tension,
- Gantry compression, and
- Track or outrigger capacity.

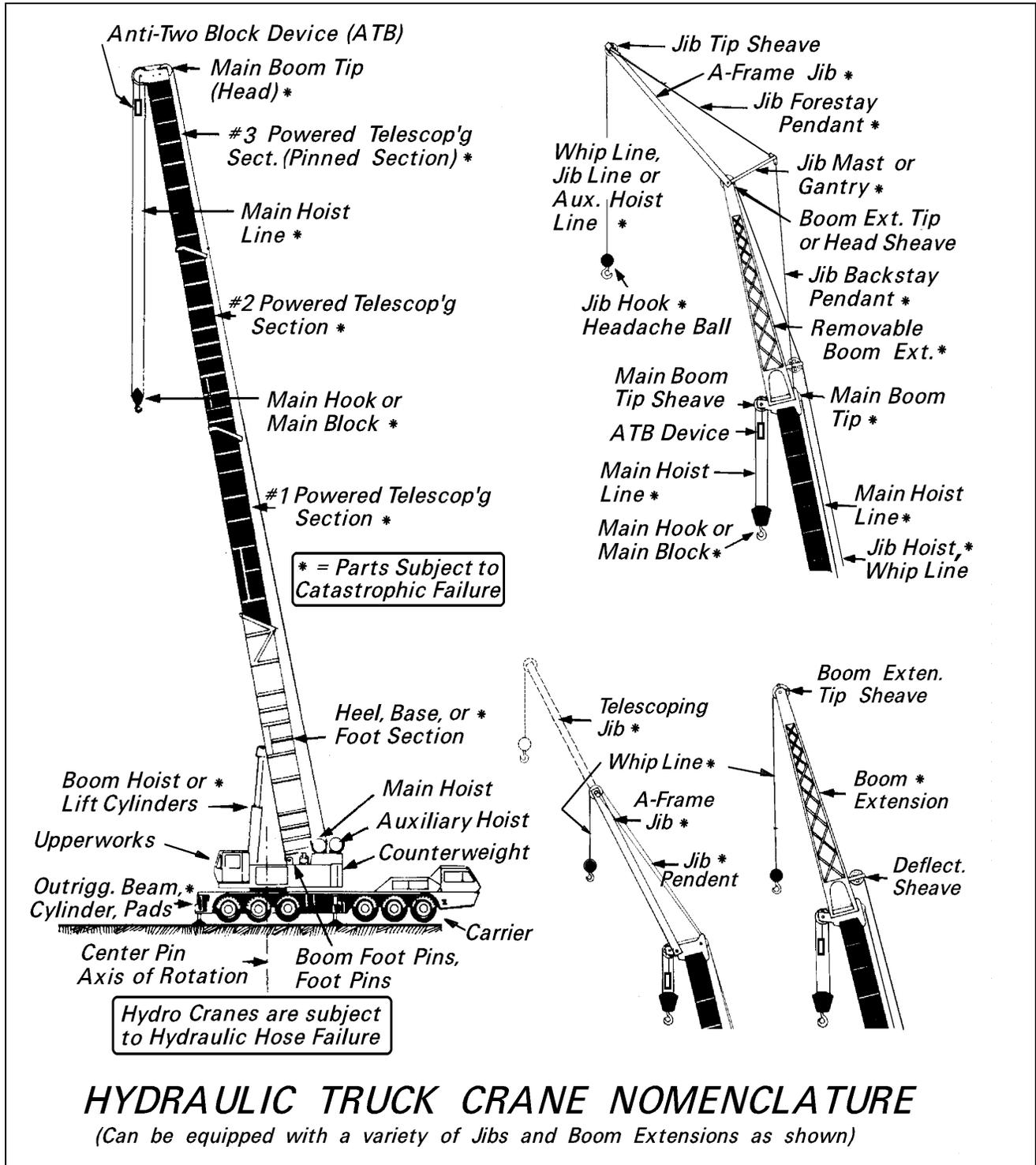
The crane load charts do not identify which crane component is limiting the capacity or what the Safety Factor (SF) may be. The minimum SF for booms and jibs is normally 3 to 1.



### LATTICE BOOM TRUCK CRANE NOMENCLATURE



Crane Components





## **VI. Crane Wire Rope—Safety Factors**

As we discussed previously, the Safety Factor (SF) for wire rope rigging is 5 to 1, which was justified on the basis of rough treatment.

For running and standing wire ropes used on cranes, the minimum safety factors are 3½ to 1 and 3 to 1 respectively.

- This lower SF assumes that wire rope on cranes receives better care and more frequent inspection than wire rope for rigging.
- An SF of 5 to 1 may be used on whip lines.

The 3½ to 1 SF is most often used for the main boom hoisting since it usually is reeved into multi-part line.

The wire rope originally supplied with the crane that is used for the main boom may be stronger (special improved plow) instead of the most common type wire rope that is used for slings (improved plow).

- The crane load charts will usually contain a table that specifies the type of wire rope that was originally supplied and what SF and safe working load are recommended.
- We will work with one of these tables in Module 2 Unit 1 of this class.

At a US&R incident, we will need to be assured that the crane's hoisting ropes are the type that were originally supplied or make the required adjustment to the load capacity for the wire rope. The difference in strength between special improved plow and the more common improved plow is about 10 percent and, for most lifts, will not govern the capacity of the crane.

The whip line is often supplied with non-rotating wire rope, and an SF of 5 to 1 will be specified.

- This type of wire rope also has a lower strength “normal” wire rope.
- Again, this information should be found in the load charts.

All involved should make sure that the cranes dispatched to the US&R incident are in a well-maintained condition that would justify this lower SF.



## **VII. Crane Blocks and Beams**

### **Use of Crane Blocks**

Blocks are used when loads to be lifted exceed the safe working capacity of single wire rope or to change the direction of a pull.

Mechanical advantage may be gained by running the wire rope over a series of sheaves. Without consideration of friction, the load capacity is increased proportionally to the number of ropes (parts of line) traveling between the sheaves.

- However, the length of travel of the load is reduced in reverse proportion to the increase in capacity of the system.
- Since friction is present when using crane blocks coupled with wire rope blocks, the actual load increase is something less, as indicated in the adjacent slide.

Crane blocks are quite heavy in order to help downfall the hook when unloaded. Wire rope blocks are much lighter since they are not subjected to the abuse of crane blocks (hook blocks). They are equipped with cheek straps that provide added strength between the end attachments and the sheave center pins.

Snatch blocks are used in many rigging situations to change the direction of most any type of rope without having to thread the rope through the block.

- The force on the snatch block varies depending on the angle of the lead and load lines.
- If the two lines are parallel, the block load is double the lift load.
- As the angle increases, the load on the block decreases.

The condition of all sheaves is very important since the wire rope travels over them under heavy loading conditions. The sheave grooves should be checked to ensure that the groove bottom has an arc of support of at least 120 degrees (preferably 150 degrees).

### **Reeving**

Reeving is the placing of wire rope on the crane/hook (moving) block and the wire rope (stationary) block. There are two common types of reeving: lacing and square reeving.

Tips on reeving from the IPT manual:

- If a stationary block has more than two sheaves, the lead line should be placed in the center sheaves to balance the block under load.
- When both blocks have the same number of sheaves, the dead end is attached to the stationary block. If the number of sheaves varies, place the dead end on the block with fewer sheaves.
- The dead end should be fed through the blocks where the lead end exits.
- Before reeving, place the blocks as closely together as possible.



## **Spreader and Equalizer Beams**

These high strength devices are used to perform various tasks. Any of these lifting devices should be designed by a professional engineer and have their capacity clearly stamped on them. They should be tested for at least 125 percent of rated capacity.

## **Two Blocking**

Two blocking occurs when the hook block or headache ball makes contact with the sheaves at the boom tip. This action can cause the hoist rope to break, which could lead to the load falling and/or the boom being pulled over backwards.

Two blocking most commonly occurs with telescopic booms. When the boom is extended, the block will be raised unless the hoist rope is paid out.

It can also occur when a lattice boom (or hydraulic boom) is lowered since the distance between the boom tip and the hoisting drum will be increased.

Anti-two block devices are included on most modern hydraulic, telescoping booms.

- The most effective system will sense when the block nears the tip, and when activated, it will disable the boom extension mechanism.
- Other devices cause a warning message (sound, etc.) to be sent to the operator.

## **VIII. Crane Accident Summary**

As with most accidents, human error causes most crane accidents.

According to the International Union of Operating Engineers (IUOE), over half of crane accidents relate to crane setup.

The causes that relate to setup include:

- Ground subsidence beneath outriggers/outriggers blocking,
- Soft footing for crawlers,
- Failure of outrigger blocks,
- Crane slipping off blocks,
- Operator neglect during setup,
- Lifting boom without outriggers, and
- Changing boom and/or counterweights without outriggers.

Other causes include:

- Violent control movements,
- Boomed out beyond safe working radius,
- Overload,
- Out of level,
- Boom collapse—backwards and structural failure,
- Boom hoist failure,
- Outrigger structural failure, and High winds.

We will further discuss Crane Accidents later in this training



## **Mobile Crane Fatalities**

The leading by far cause of fatalities that have occurred during the operation of mobile cranes is contact with power lines. Special safety rules apply when cranes are required to operate near them.

- Depending on power line voltage, the required clearance from live wires varies from 10 to 25 feet.
- A spotter/signaler must be stationed near the clearance distance from the power line whenever a crane is within boom's length of the limit of approach.
- This person should have no other job than to signal the crane operator regarding the boom's position relative to the power line.

## **IX. Crane Hand and Voice Signals**

### **How a Crane Moves The Load**

Prior to discussing Mobile Crane Hand and Voice Signals, we need to understand how a crane moves the load in response to the signals.

- How a crane moves vertically (based on movement of the boom)
  - ◆ When the signal "Boom-down" is given, the boom moves in an arc about its pin support. Therefore the load will move down and forward. Boom-up would, of course be the opposite – up and in.
  - ◆ In the case of a hydraulic boom, when given the signal to "Boom-in", the load will follow the tip of the boom out and will also move up (as discussed under Two-Blocking)
  - ◆ The only way that the load can be only moved vertically using one signal is to "Hoist-up" (or down).
- How a crane moves horizontally (based on movement of the boom)
  - ◆ When the signal "Swing-right" (or left) is given the boom and load will swing in an arc about the center pin. The load will move to the right and in.
  - ◆ If one wishes to move the load only to the right (or left) it would require two commands. ( swing-right and boom-down)

### **Implementing Mobile Crane Hand and Voice Signals**

Positive Signaling between the Rigger on the ground and the Crane Operator is essential to safe operations. The National Commission for the Certification of Crane Operators (NCCCO) has established Standard Hand and Voice Signals for Mobile and Tower Cranes.

- These signals will become National Standards.
- Only one qualified person should be signaling, and both operator and signal person need to meet prior to the start of lifting operations to assure proper communication.
- Signaling techniques vary, and body language is often used for emphasis, so the signal person must be in clear view of the operator at all times. Swing commands are given from the operators perspective
- The Hand Signals are the same as those that have been published in industry handbooks for many years.



## **Implementing Mobile Crane Hand and Voice Signals (continued)**

NCCCO has also adopted **Voice Signals**, in order to provide this needed communication when conditions do not allow for a clear view of the signaler by the crane operator.

- Voice signals are normally transmitted by hand-held radio or telephone, and must be clear and loud in order to be heard over the noise of the machinery.
- The radio or telephone devices and communication must be checked prior to any lifting, to ensure that instructions can be clearly understood with normal operational noise.
- The NCCCO Voice Signals must contain the following 3 elements.
  - ◆ Function and direction.
  - ◆ Distance and/or speed.
  - ◆ Function stop.
- Acceptable voice signal functions are:
  - ◆ Hoist, or Raise the load : Lower.
  - ◆ Raise/Lower boom, or Boom up/down.
  - ◆ Extend/Retract boom, or Telescope out/in.
  - ◆ Raise boom and lower the load, or Boom up and lower the load.
  - ◆ Lower boom and raise the load, or Boom down and raise/hoist the load.
  - ◆ Swing right, Swing left.
  - ◆ Use main hoist, use whipline/auxiliary hoist.
  - ◆ Stop
- Voice Crane Signal Examples:
  - ◆ Swing right 50ft, 25ft, 10ft, 5ft, 2ft, swing stop
  - ◆ Lower load 100ft, 50ft, 25ft, 10ft, 5ft, 2ft, lower stop.
  - ◆ Hoist load slow, slow, keep hoisting slow, hoist stop

It is the HERS responsibility to assure that these standards are understood by all operators and riggers that are employed at the US&R Incident.

- If local custom is to use other signals, the HERS must determine what set of signals will be most effect and make sure that all involved understand what is to be used.
- The standard Crane Hand Signals are shown on the next page

## **X. Unit Summary**

As with all US&R operations, safety is very important, and all task force members who are involved must take the responsibility for assuring that the crane operator and riggers, as well as all task force members, understand and follow all safety rules involving the use of cranes.

Positive communication is essential, and all work must be coordinated during pre-lift briefing sessions. The HERS must take the lead in ensuring that all operations will be undertaken with positive communication and signaling, and at minimum risk



<h1>CRANE SIGNALS</h1> <p>ALWAYS STAND IN CLEAR VIEW OF YOUR CRANE HOIST ENGINEER</p> <p>BE SURE TO STAY A SAFE DISTANCE FROM HOOK, BLOCK OR BOOM</p> <p>Published by SPECIALIZED CARRIERS &amp; RIGGING ASSOCIATION</p> <p>In accordance with the American National Standards Institute</p>		<p><b>HOIST</b></p> <p>HOIST: With forearm vertical, forefinger pointing up, move hand in small horizontal circles.</p>	<p><b>LOWER</b></p> <p>LOWER: With arm extended downward, forefinger pointing down, move hand in small horizontal circles.</p>	
<p><b>USE MAIN HOIST</b></p> <p>USE MAIN HOIST: Tap list on head, then use regular signals.</p>	<p><b>USE WHIP LINE</b></p> <p>USE WHIP LINE: (Auxiliary Hoist) Tap elbow with one hand; then use regular signals.</p>	<p><b>RAISE BOOM</b></p> <p>RAISE BOOM: Arm extended, fingers closed, thumb pointing upward.</p>	<p><b>LOWER BOOM</b></p> <p>LOWER BOOM: Arm extended, fingers closed, thumb pointing downward.</p>	
<p><b>MOVE SLOWLY</b></p> <p>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)</p>	<p><b>RAISE THE BOOM AND LOWER THE LOAD</b></p> <p>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.</p>	<p><b>LOWER THE BOOM AND RAISE THE LOAD</b></p> <p>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.</p>	<p><b>SWING</b></p> <p>SWING: Arm extended, point with finger in direction of swing of boom.</p>	
<p><b>STOP</b></p> <p>STOP: Arm extended, palm down, move arm back and forth horizontally.</p>	<p><b>EMERGENCY STOP</b></p> <p>EMERGENCY STOP: Both arms extended, palms down, move arms back and forth horizontally.</p>		<p><b>TRAVEL</b></p> <p>TRAVEL: Arm extended forward, hand open and slightly raised, making pushing motion in direction of travel.</p>	<p><b>DOG EVERYTHING</b></p> <p>DOG EVERYTHING: Clasp hands in front of body.</p>
<p><b>TELESCOPING BOOM TWO HANDS</b></p> <p>EXTEND BOOM BOTH FISTS IN FRONT OF BODY WITH THUMBS POINTING OUTWARD</p>	<p><b>TELESCOPING BOOM TWO HANDS</b></p> <p>RETRACT BOOM BOTH FISTS IN FRONT OF BODY WITH THUMBS POINTING TOWARD EACH OTHER</p>	<p><b>TELESCOPING BOOM ONE HAND</b></p> <p>EXTEND BOOM ONE HAND SIGNAL: ONE FIST IN FRONT OF CHEST WITH THUMB TAPPING CHEST</p>	<p><b>TELESCOPING BOOM ONE HAND</b></p> <p>RETRACT BOOM ONE HAND SIGNAL: ONE FIST IN FRONT OF CHEST, WITH THUMB POINTING OUTWARD AND HEEL OF FIST TAPPING CHEST</p>	