LD-777 Shreve

Accident Investigation Board Report

Headquarters Command Briefing

Findings and Recommendations 2 Sep 2014

Locks Maintenance Meeting 11 Feb 2015

Floating Crane “HENRY M. SHREVE”

“HENRY M. SHREVE” Upon Delivery – 2001

- Design management and contract administration by the USACE Marine Design Center
- Barge and pedestal designed by Brown & Root Services to ABS certification requirements
- Crane selection from Commercial, Off The Shelf options
- Ederer Crane assembled by Vanguard Services in TN., delivered 2001
- Dimensions: 300-ft x 100-ft x 13.5-ft
- 550-Ton Over-the-Stern lifting capacity; 460-Ton Fully Revolving
- LRD Regional Asset operated and maintained by Louisville District
- Crane has one full-time Operator and one full-time equipment mechanic.

Purpose

The purpose of this briefing is to inform Headquarters USACE Command of the findings and recommendations of the board's investigation

Expected Outcome

Headquarters USACE understanding and acceptance of the BOI findings and recommendations

References

- AR 385-10, *Army Safety Program*, 4 October 2011
- DA Pam 385-40, *Army Accident Reporting,* 25 February 2010
- ER 385-1-99, *USACE Accident Investigation and Reporting,* 15 March 2010
- EM 385-1-1, *Safety and Health Requirements Manual,* 15 September 2008 (with changes 1-7)
- USACE OPORD 2011-82, *Crane/Hoist/Rigging Action Plan,* 23 November 2011
- ASME B30.8-2010, *Floating Cranes and Floating Derricks*, 2010

Agenda

- Accident Investigation Board Team Members
  - AVID Controls Report
  - Ederer Boom Hoist Drum Brake Analysis
  - MDC and HDC Engineering Analysis
- Equipment, Site, and Operational Orientation
- Accident Outcomes
- Failure Sequence
- Causes of the Accident
  - Direct
  - Indirect
- Recommendations

Accident Investigation Board Members

- Board President
  - LTC Chris Riemer, Deputy Commander, Pittsburgh District

- Board Members (Voting)
  - Mr. Don Fogel, Supervisory Operations Manager, Pittsburgh District
  - Mr. John Cannon, Regional Technical Crane Safety Specialist, NWP

- Technical Advisors (Non-Voting)
  - Mr. Cary Hahn, Crane/Derrick Boat Operator, Rock Island District
  - Mr. Greg Lee, Supervisory Naval Architect Chief Design Branch, Marine Design Center, Philadelphia, PA
  - Mr. Michael Tustin, Safety & Occupational Health Manager, Great Lakes and Ohio River Division

Additional Investigative Actions

- Received AVID Controls report on deficiencies in the crane electrical system

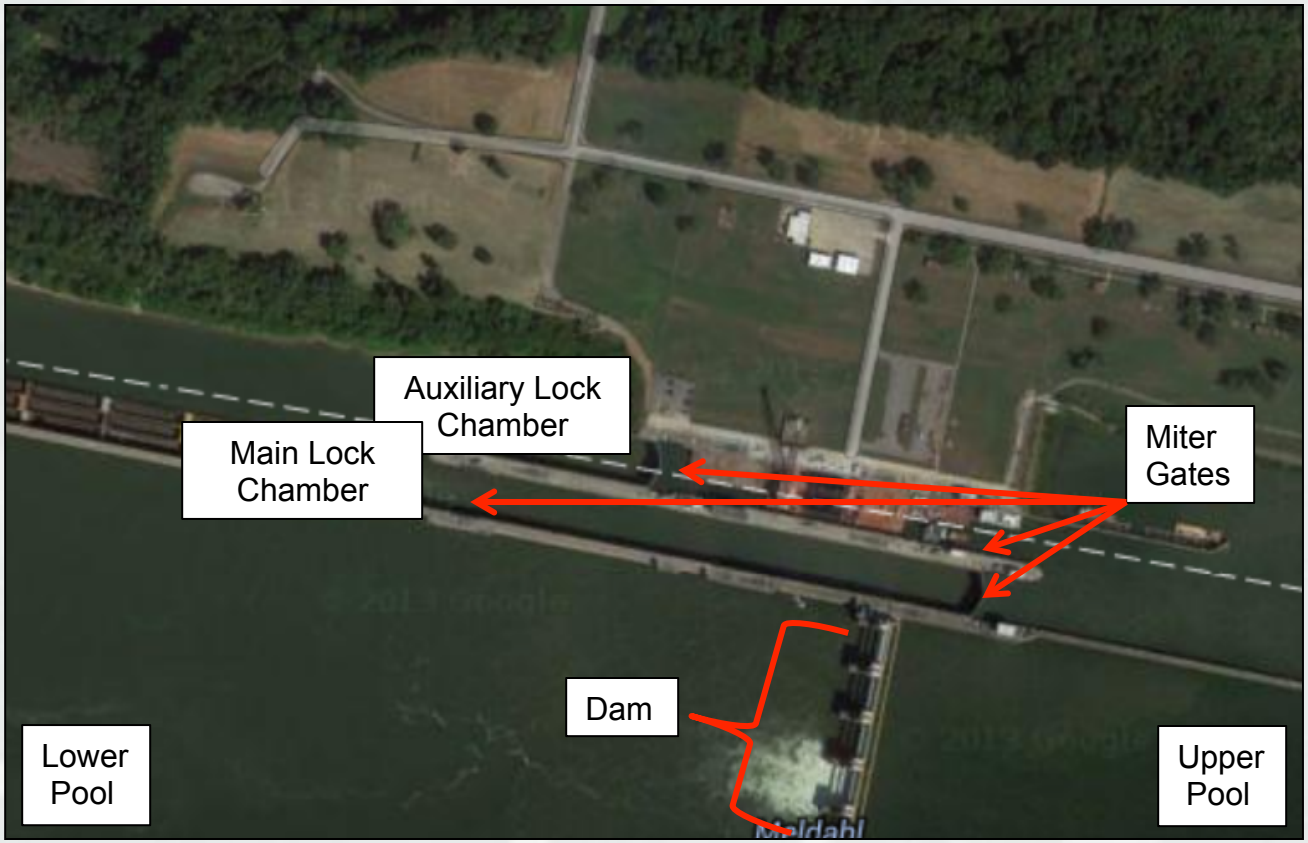
- Confirmed with Ederer that the boom hoist drum brake did not meet ASME B.30 standards

- Marine Design Center and Hydro Power Design Center conducted independent electrical and mechanical engineering analysis

USACE Huntington District
Captain Anthony Meldahl Locks and Dam

The Captain Anthony Meldahl Locks and Dam are located in Felicity, Ohio approximately 35 miles southeast of Cincinnati, Ohio

Captain Anthony Meldahl Locks and Dam



- The Captain Anthony Meldahl Locks and Dam was completed in 1965.
- The dam is a non-navigable, high lift, gated dam with a top length of 1,756’ .
- The lock facility consists of two parallel locks with miter service gates.
  - The primary lock chamber is 110’ by 1200’
  - The auxiliary lock chamber is 110’ by 600’
- The normal lift between pools at the facility is 30’

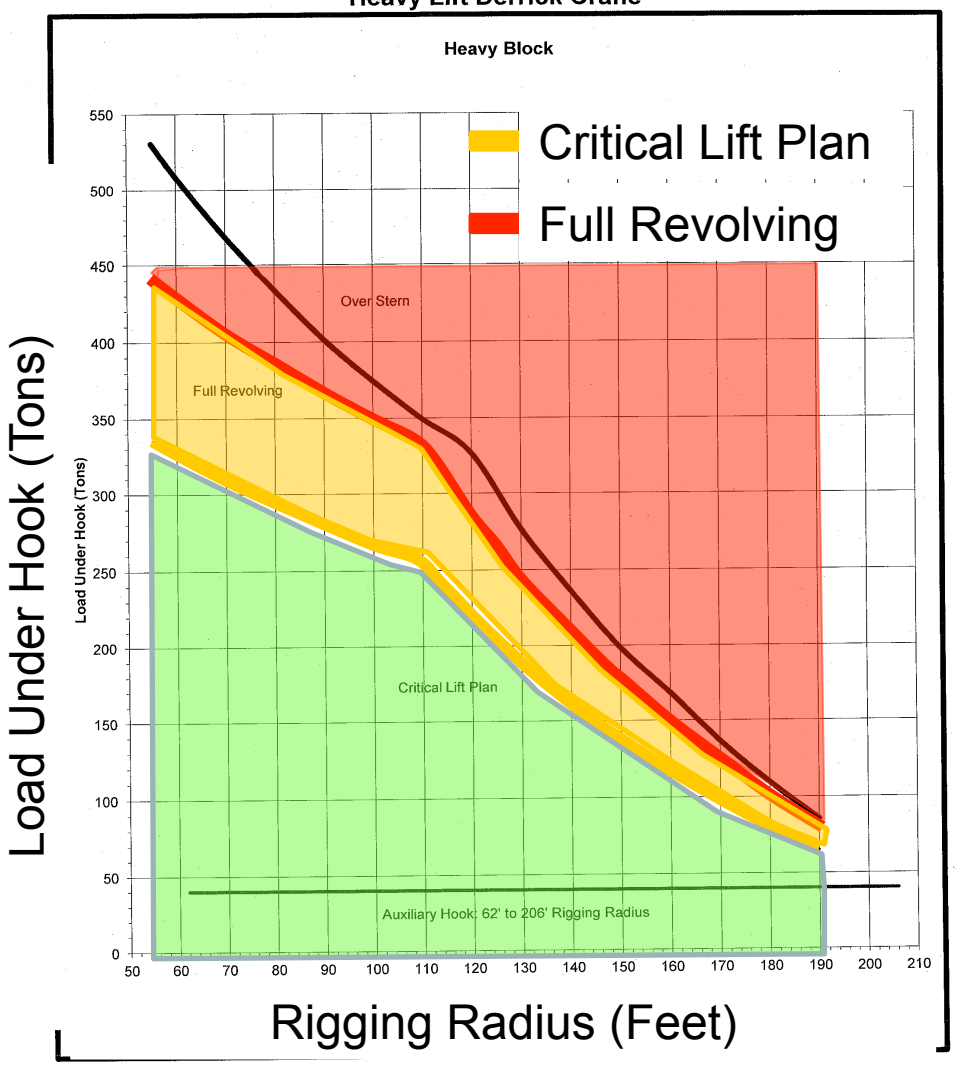
Mission

Huntington District Repair Fleet with support from the LRD Floating Crane "HENRY M. SHREVE" replaces the primary chamber upstream miter gates at Meldahl Locks and Dam between 29 July and 22 November 2013. The key initial task was to remove the new gates from contractor owned barges and stage them at the facility for installation later in the project.

Key Personnel

- GS-12 Project Engineer – 23 years experience with the COE and 13 years as a Project Engineer, Operations Division
- Maintenance General Supervisor – 20 years experience with the LRH Repair Fleet, serving on a 120-day developmental assignment at the time of the accident
- Shift Foreman - 4 years experience with the LRH Repair Fleet, 4 months as shift foreman
- Shift Leader – $3^1/_2$ years experience with the LRH Repair Fleet, serving in a temporary capacity. Dual-hatted as crane signal person.
- Derrickboat Master – Over 51 years of experience in marine repair and crane operation
- Five of nine employees assigned to the first shift when the accident occurred were new or had little relevant experience with heavy lift crane operations.
- All employees were properly trained and certified for crane operations.

LD-777 Henry M. Shreve
Heavy Lift Derrick Crane

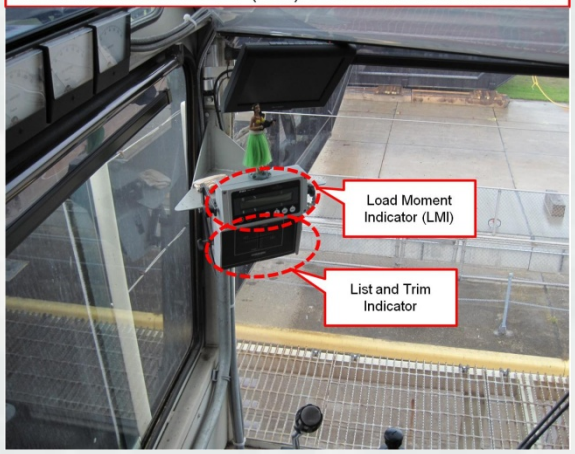


U.S. ARMY CORPS OF ENGINEERS
Louisville District
Louisville Repair Station
2605 Shippingport Drive
Louisville, KY 40212
Phone (502) 778-6611

Date 2/10/05
Revision 1
From O M Manual
Ederer S.O. NO. F-2567
Washington Model 52

Operational Aids and Controls

Load Moment Indicator (LMI) & List and Trim Indicators



Close Up – List / Trim Indicator

Crane Operator Controls Right Side of Cab

Close Up – Load Moment Indicator

Tape over LMI Audible Alarm Speaker

Timeline for 1 August 2013

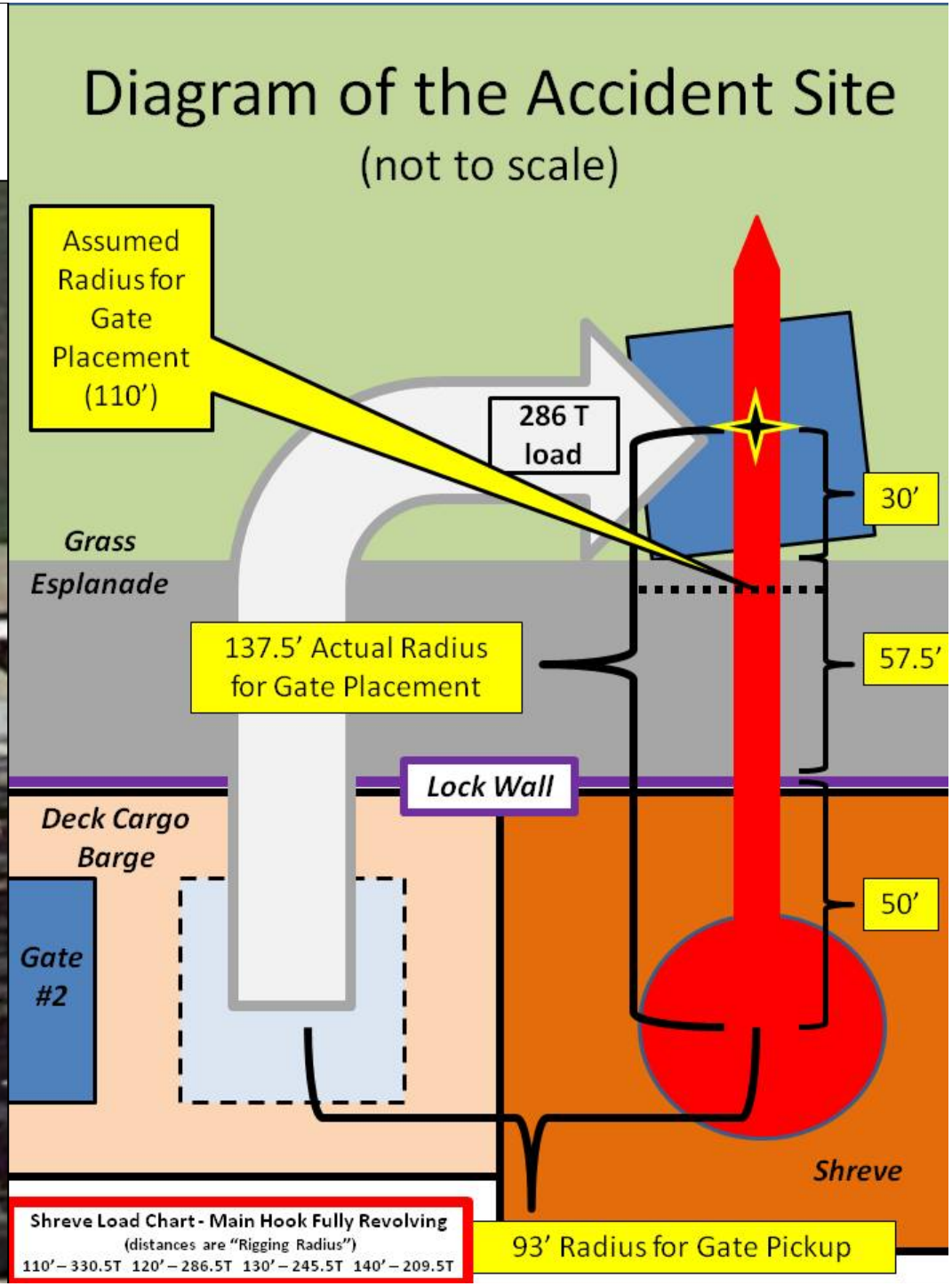
- 0700 - Safety Meeting
- Morning Activities
  - Rig the lifting beam on the bow of the Shreve
  - Reconfigure the fleet in Auxiliary Chamber
  - Realign cribbing to avoid trench in grass
  - Slew boom 180 degrees past port to rig the load over stern of Shreve
- 1000 - Collateral Duty Safety Officers arrive
- Lunch
- 1330 – final meeting and commence gate lift
- 1400 – accident occurs

Shreve Performing Gate Lift Prior To Failure

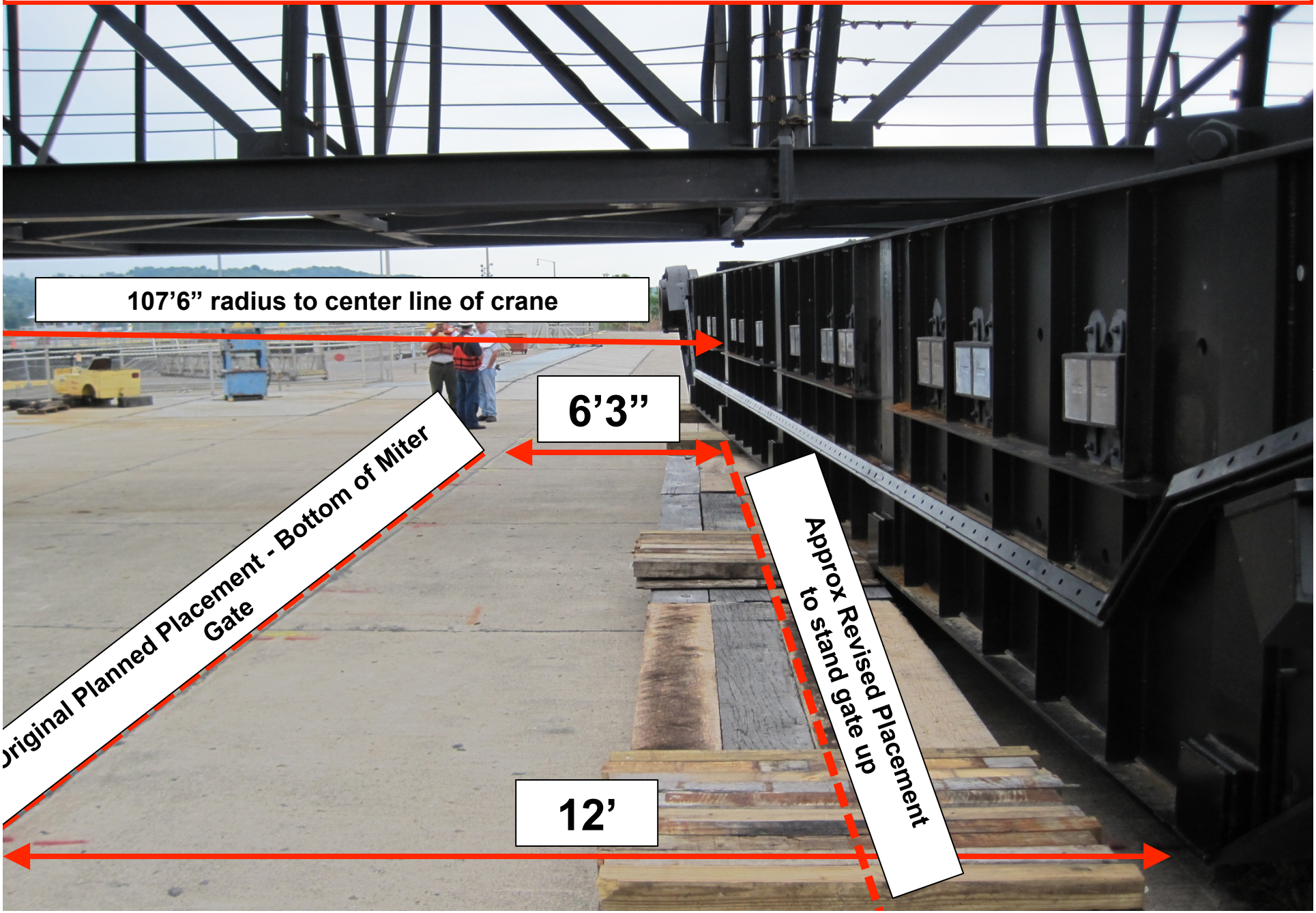
PLAY SURVEILLANCE CAMERA VIDEO

Shreave Failure 1 AugRotated.MOV

Imagery of Previous Gate Lift



Miter Gate Placement – Planned vs. Actual

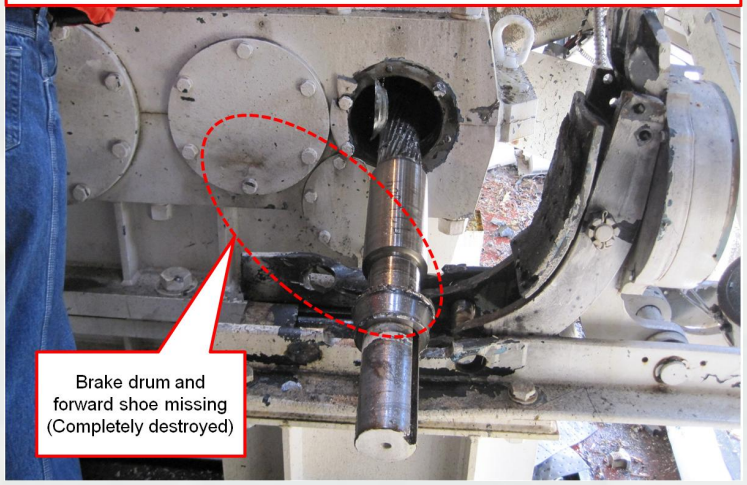


Accident Outcomes

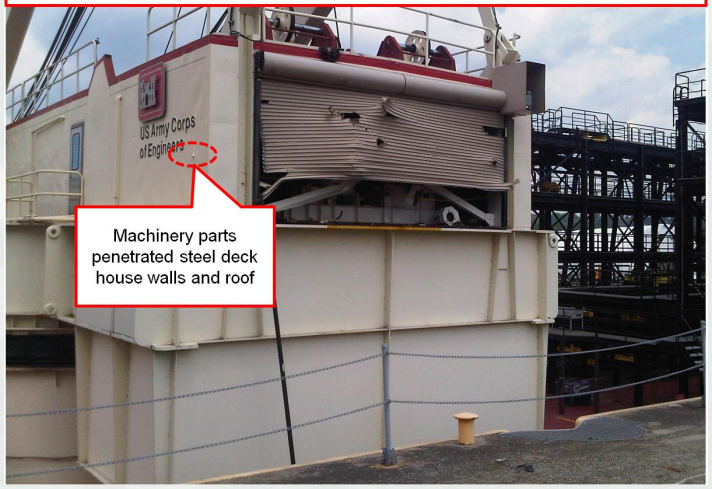
- No injuries to personnel
- Estimated $10M in damage to the Shreve
  - Extensive damage in machinery housing
  - Boom destroyed and complete loss of running rigging
  - Damage to crane and vessel electrical systems
- Estimated $7M in indirect costs to USACE
- Long term impacts on LRD O&M Program

Machinery Housing Damage

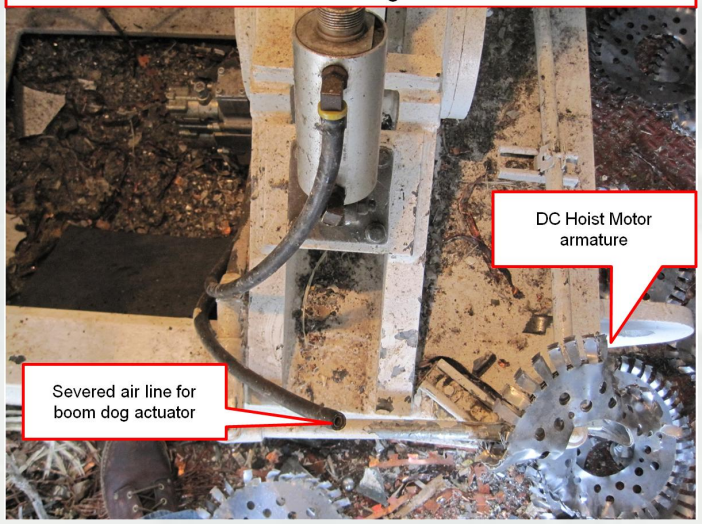
Catastrophic Failure of Boom Hoist Drum Motor Brake and Reduction Gear



Damage to Machinery House Door from Boom Hoist Drum Brake Explosion



Failed Boom Dog Actuator



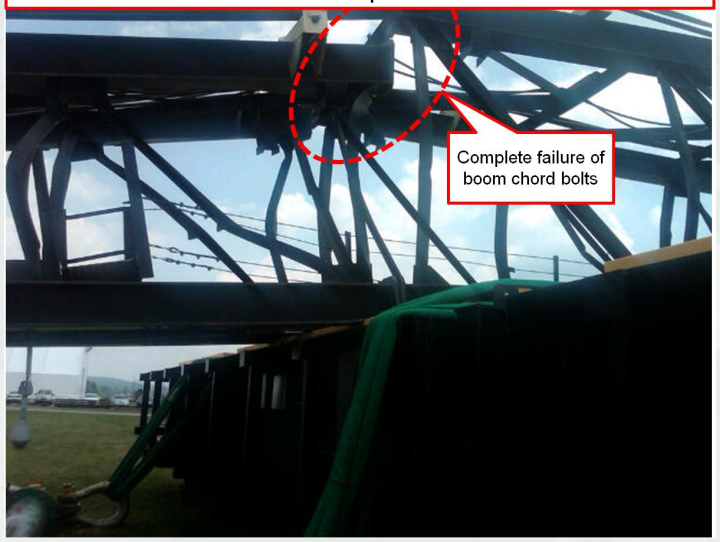
Disengaged Boom Dog

Boom Damage

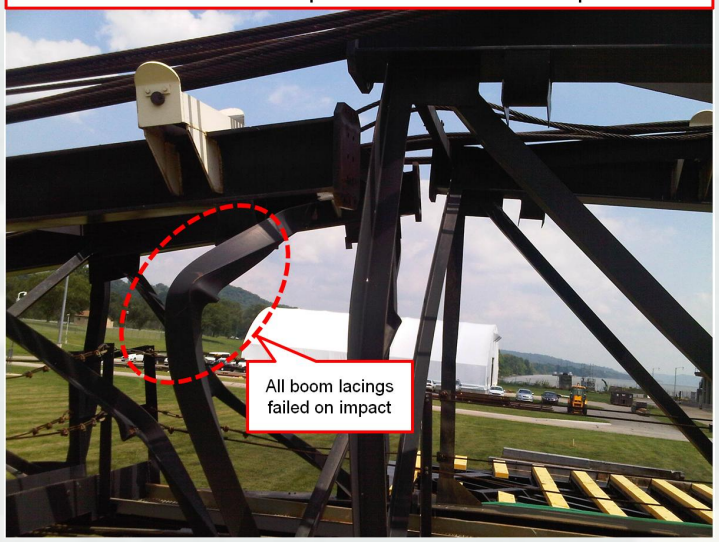
Failed Boom on Top of Miter Gate

Failed Boom Tip Extending Past the Top of Miter Gate

Failed Boom Tip Connection

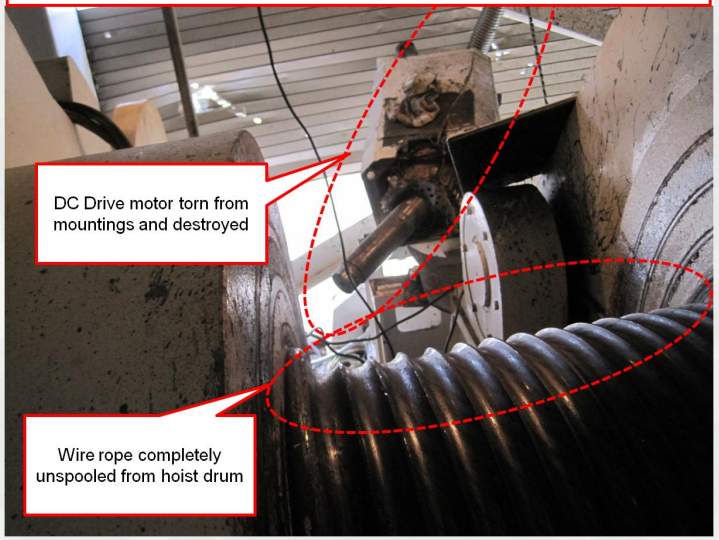


Failed Boom Tip Connection Close Up



Vessel and Crane Electrical Damage

Boom Hoist Machinery Damage



Tripped Circuit Breaker on Main Generator

Arc Flash Damage Under the Whirler

Blown Out Electrical Conduit Under the Whirler

First Failure: Electrical Design and Construction

The first failure was electrical. Over time, design and construction deficiencies within the crane's electrical system had set the conditions for an electrical failure. The first event in the chain was a major ground fault that caused a loss of power in the crane.

Photo 25: Overpacked Conduit with Unarmored Cables

Photo 26: Damaged Cable Insulation

- The crane was purchased as a Commercial Off the Shelf system
- Since the crane was ASME B.30 compliant, it was not subject to the USACE construction quality management program's design review and submittal process
- Acceptance testing focused on functionality
- Post accident investigation revealed:
  - ***Too many 90 degree turns in conduit runs***
  - ***Too many wires in conduit***
  - ***Wires bent over sharp edges***
  - ***Multiple cuts, chaffed wiring***
  - ***No ground protection or ground detection***

Electrical Failure Could Have Occurred At Any Time

Photo 25: Overpacked Conduit with Unarmored Cables

Photo 26: Damaged Cable Insulation

- The Shreve load bank provided a minimum load of approximately 340 KW on the generator and the generator power cables whenever the Shreve was in operation.

- The undersized cable conduit did not allow adequate cooling for the generator main cables. Heat degrades insulation over time.

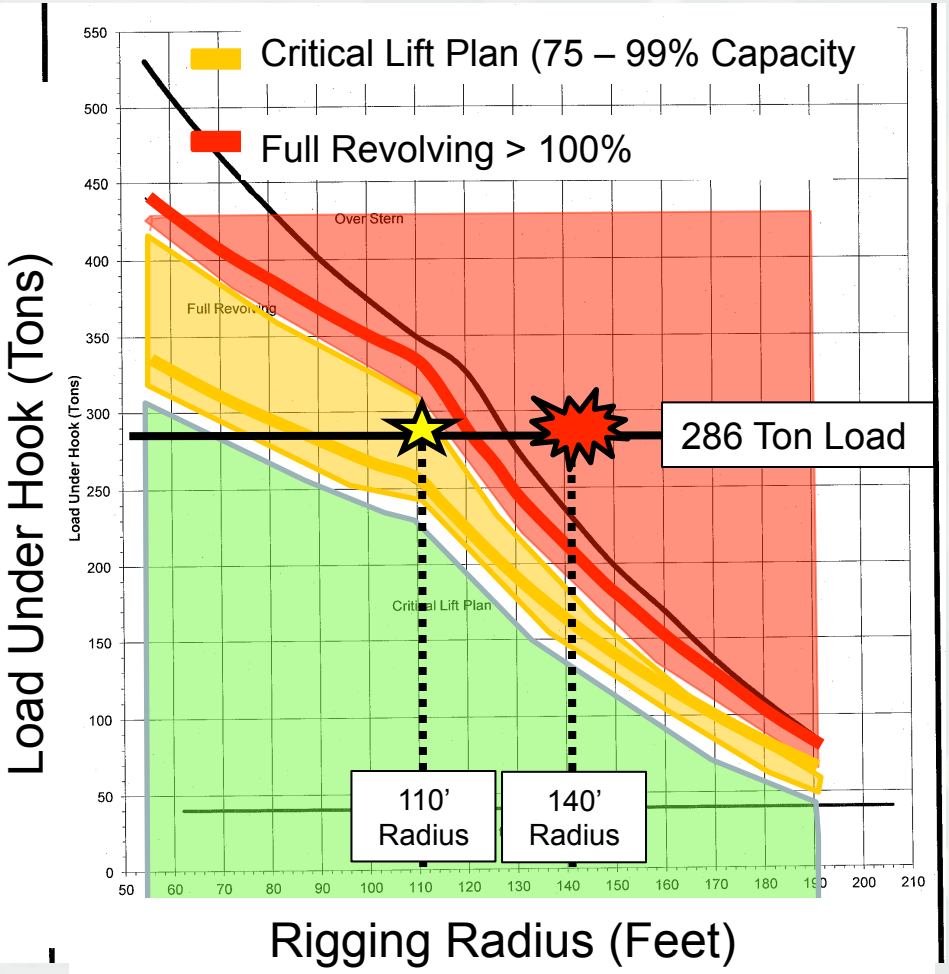
- Damaged insulation from the poor installation provided a start point for insulation break down over time under heat and current.

- Major ground fault resulted in damage to the crane's electrical system

Second Failure: Mechanical Design and Overload

- The second event in the chain was a mechanical failure.
- The dynamic braking capability of the boom hoist motor was lost as a result of the major ground fault
- By design, the boom hoist drum brake automatically locks on to arrest the load.
- Due to a design error, the boom hoist drum brake was undersized and only capable of holding 110% of the crane's rated capacity vice the 125% requirement per ASME B.30.
- The brake is designed to operate in static conditions and not to stop dynamic loads.
- The design error reduced the safety factor built into the crane from 25% to 10%.
- Operation of the crane outside of its fully revolving load chart eliminated any possibility of the undersized boom brake arresting the load. Under dynamic conditions, the torque created by the load was too great to overcome.
- The failure of the boom hoist drum brake to hold the load resulted in the falling of the load and boom. This caused extensive mechanical and structural damage to the machinery, crane housing, and boom and unspooled all of the crane's rigging.

Operation Outside of the Load Chart



- Failure to identify the requirement for critical lift planning
- Failure to physically validate the lift radius
- Improper LMI usage

Failure Sequence

The direct causes of the chain of failures that occurred on the Shreve were **design and construction deficiencies** **and** **operation of the crane outside of its load chart**.

• The first failure electrical. Over time, design and construction deficiencies within the crane's electrical system had set the conditions for an electrical failure. The first event in the chain was a major ground fault that caused a loss of power in the crane.

• The second event in the chain was a mechanical failure. When the crane lost power and with it the dynamic braking capability of the boom hoist motor, the boom hoist drum brake is designed to automatically lock on and arrest the load. Due to a design error, the boom hoist drum brake was undersized and only capable of holding 110% of the crane's rated capacity vice the 125% requirement per ASME B.30. The brake is designed to operate in static conditions and not to stop dynamic loads. The design error reduced the safety factor built into the crane from 25% to 10%.

• Due to a series of human errors, the Shreve was operating at outside of its fully revolving load chart at the time of the accident. This overloaded condition eliminated the already reduced factor of safety designed into the crane and assured the inability of the boom hoist drum brake to arrest the load. The combination of the undersized boom hoist drum brake and the crane's operation in an overloaded condition led to the mechanical and structural damage suffered by the Shreve.

Direct Cause of the Accident

The direct causes of the chain of failures that occurred on the Shreve were **design and construction deficiencies** **and** **operation of the crane outside of its load chart**.

- Design deficiencies:
  - No Ground Fault Indicator
  - Over packed conduits
  - Too many 90 degree turns in conduits
  - Undersized boom hoist drum brake not IAW ASME B.30

- Construction Quality: damage to conductor insulation during wiring

- Operation of Crane Outside of Load Chart: The overload condition eliminated the already reduced factor of safety designed into the crane and assured the inability of the boom hoist drum brake to arrest the load.

Indirect Causes of the Accident

(slide 1 of 2)

Indirect Cause #1: USACE Acquisition Process Risk

- USACE purchased a Commercial, Off the Shelf system for installation on the Shreve's hull and pedestal

- Since the system was B.30 compliant, there was no design review or submittal process

- No construction quality assurance for workmanship

- Acceptance testing focused on functionality

Indirect Causes of the Accident

(slide 2 of 2)

Indirect Cause #2: Human Factors

- Failure to identify requirement for and conduct Critical Lift Planning (thought this lift had been made before)

- Use of the crane outside of its fully revolving load chart

- Improper LMI operation due to incorrect electronic load charts loaded

Recommendation 1:
Review Acquisition Process

USACE must reassess the risk of reduced design and construction quality assurance processes in the acquisition of commercial, off the shelf equipment for installation on its vessels and facilities. The focus on functionality without attention to design standards and construction quality during procurement set the conditions for the Shreve accident and must be reconsidered in the future.

Recommendation 2:
Fleet Inspections

USACE districts should immediately check other electrically powered floating cranes to confirm/deny the presence of Ground Fault Detection Systems. Equipment should be retrofitted if necessary. A periodic megger test program should be considered to ensure electrical systems on heavy lift equipment are fully functional.

Recommendation 3:
Load Chart Validations

- All activities should ensure that each crane and derrick has an up-to-date Naval Architectural Analysis.

- A hard copy of the floating service load charts shall be located in the cab of the crane within view of the operator

- The appropriate electronic load charts are loaded in the load-moment indicator (LMI) system

Recommendation 4:
Improve C2 of Critical Lifts

USACE must focus on improving the command and control process for critical lifts. Critical lift plan development must be a deliberate and coordinated effort between the crane operator, signalmen, and riggers under the direction of the lift supervisor. Lift planning must include physical validation of the radius for the entire range of each lift and ensure the loads and radii are within the safe working limits of the load chart. An experienced leader must be appointed to serve the role of lift supervisor and manage the operation in accordance with the established standards.

Recommendation 5: Documentation and Audits

Document inspections, maintenance, and training in accordance with established standards. There is sufficient guidance, regulation, and doctrine in place; it is the responsibility of first line supervisors to enforce existing policy for second line supervisors to validate compliance. Districts should audit crane training programs to ensure compliance with Corps of Engineers Safety and Health Requirements Manual, EM 385-1-1. USACE High Hazards Working Group (HiHWG) should provide program quality assurance through random inspections on behalf of Headquarters USACE.

Questions?

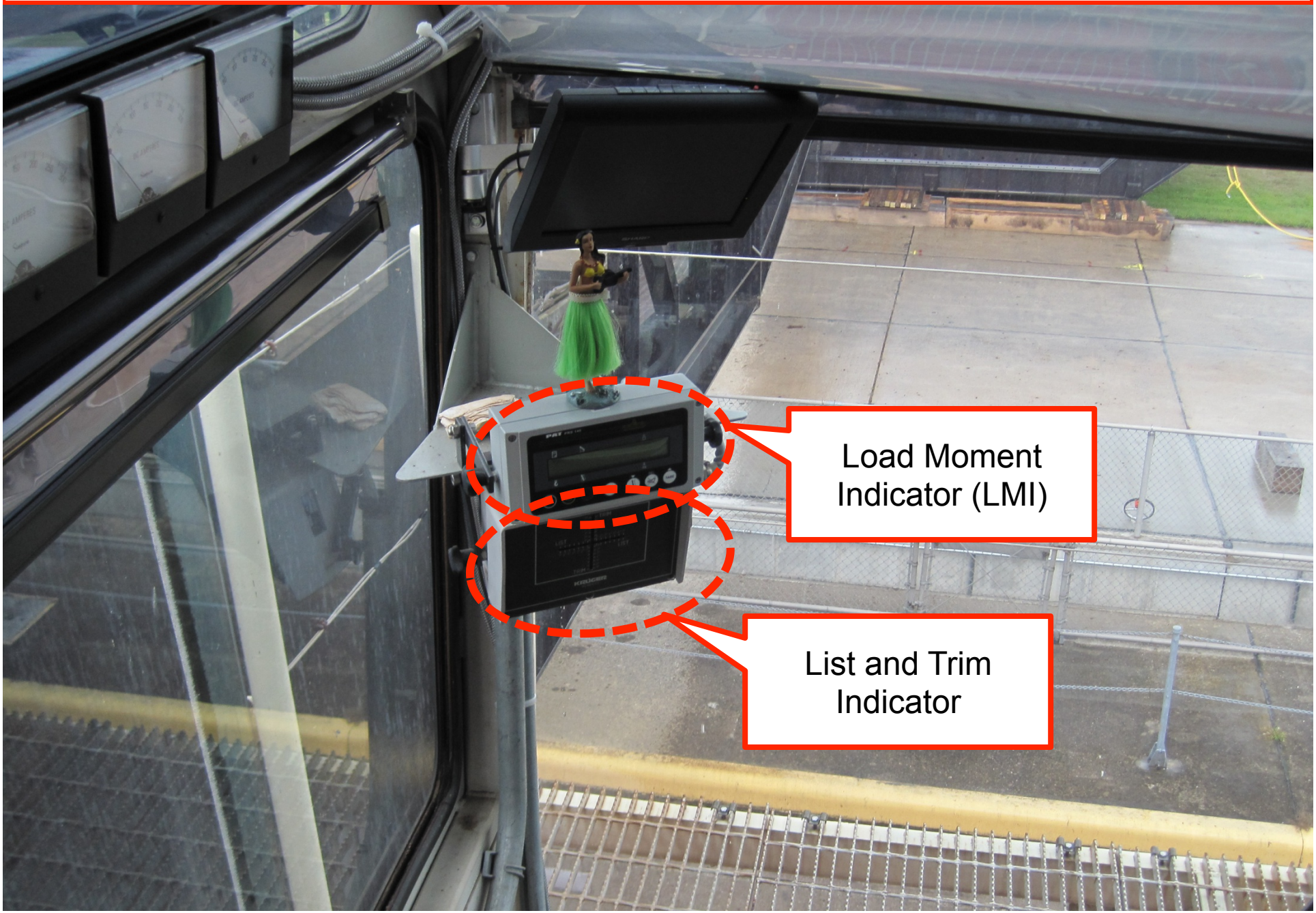
Human Factors

- All participants involved in this incident were trained; however, training documentation was incomplete and not in accordance with the EM-385-1-1.
- Five of nine employees assigned to the first shift when the accident occurred are new or had little relevant experience with heavy lift crane operations.
- Failure to develop and discuss a critical lift plan is a primary indirect cause of this accident.
- Maintenance and Record Keeping – Inadequate record keeping of maintenance performed on the crane was a present and contributing factor in this incident. Routine maintenance has not been recorded; therefore, the condition of the crane and its components was not fully known.

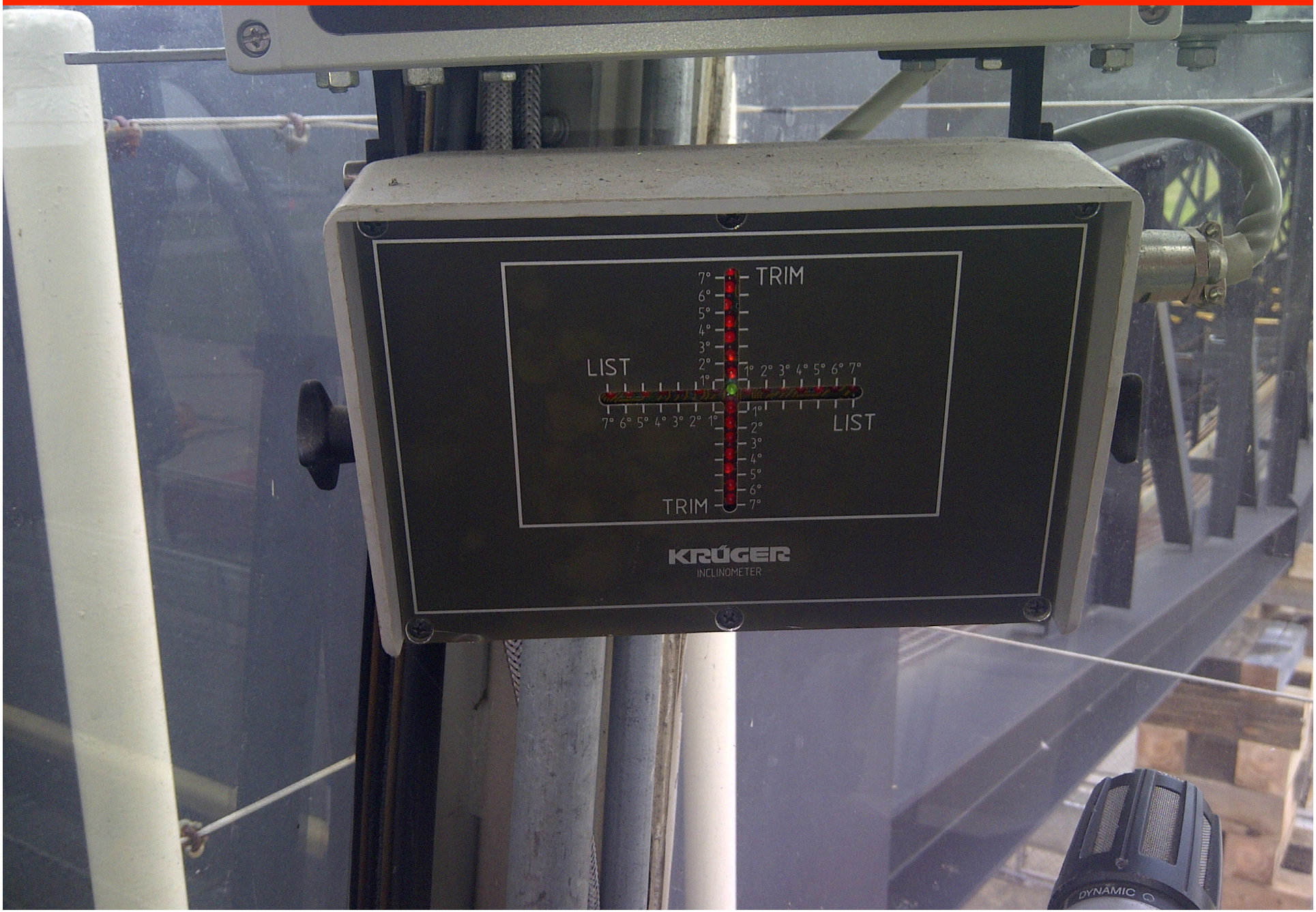
Materiel Factors

- Documentation of a current load test, daily and monthly inspections of the crane were not available to demonstrate adequacy and safety of the crane prior to the lift.
- Failure to have the correct load chart in view of the operator
- The load-moment indicator (LMI) failed to alarm or otherwise warn the operator of an overload condition. Audible alarm was taped over.

Load Moment Indicator (LMI) & List and Trim Indicators



Close Up – List / Trim Indicator



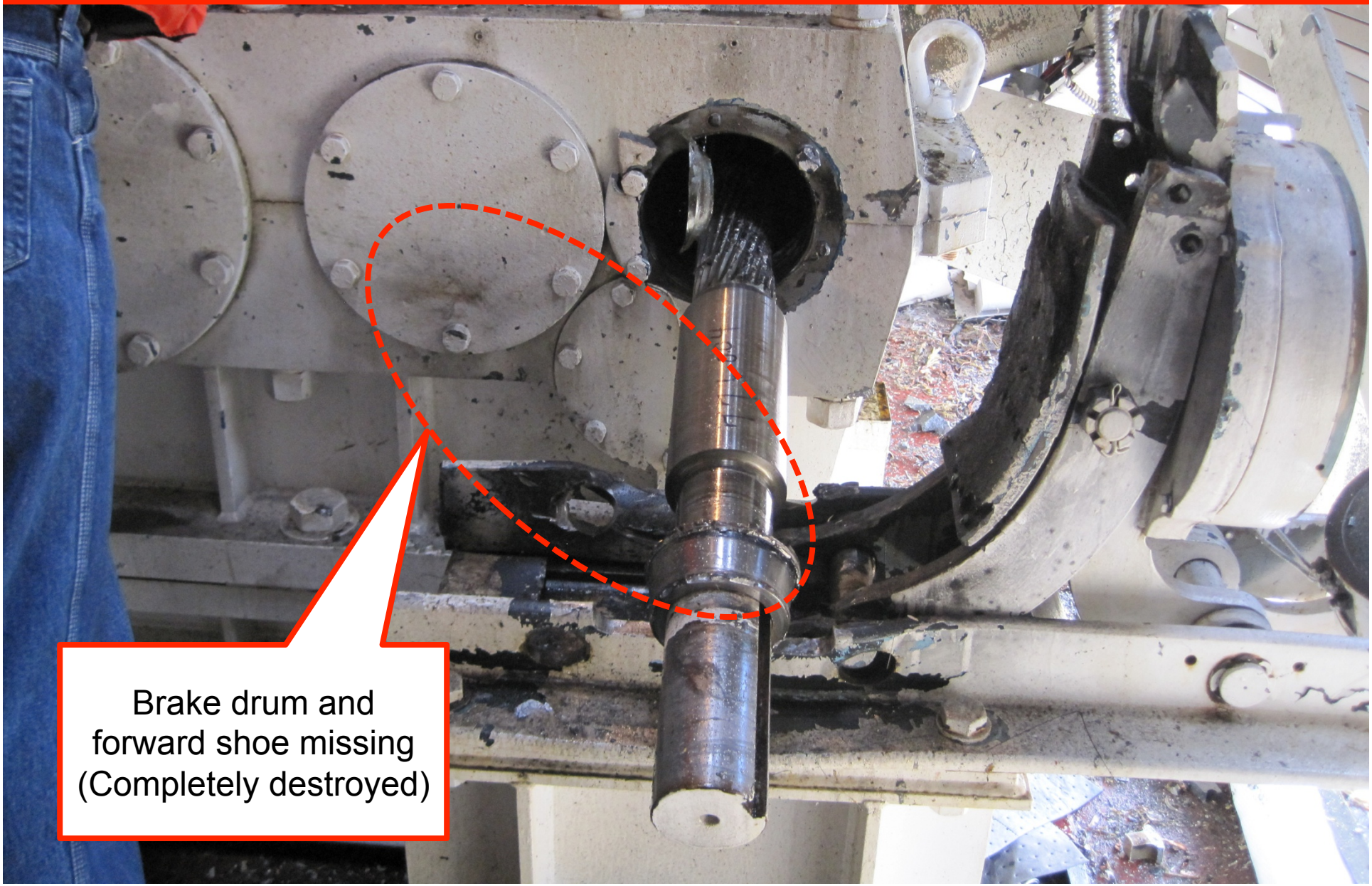
Close Up – Load Moment Indicator

Tape over LMI Audible Alarm Speaker

Crane Operator Controls – Left Side of Cab

Crane Operator Controls Right Side of Cab

Catastrophic Failure of Boom Hoist Drum Motor Brake and Reduction Gear



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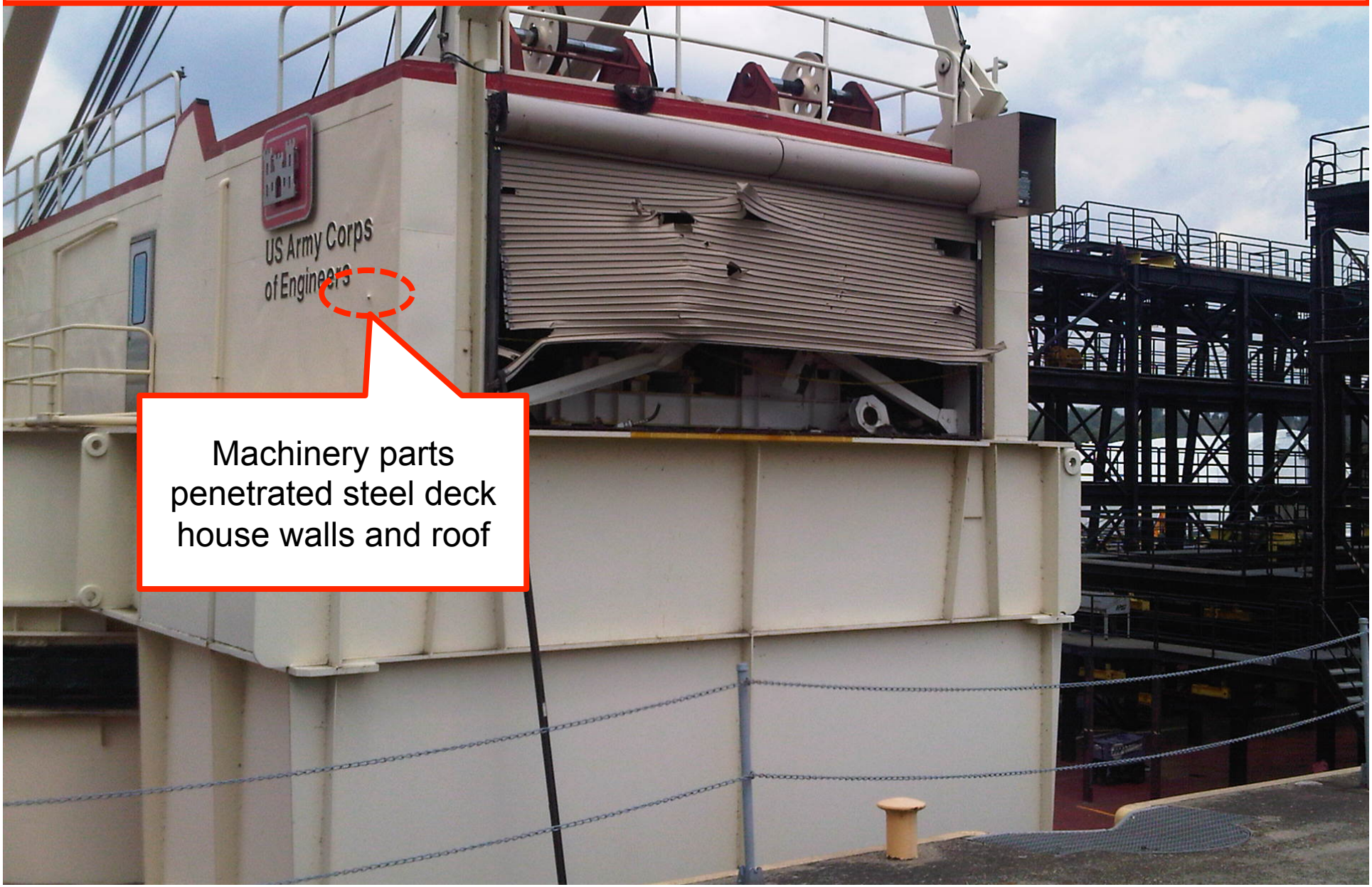

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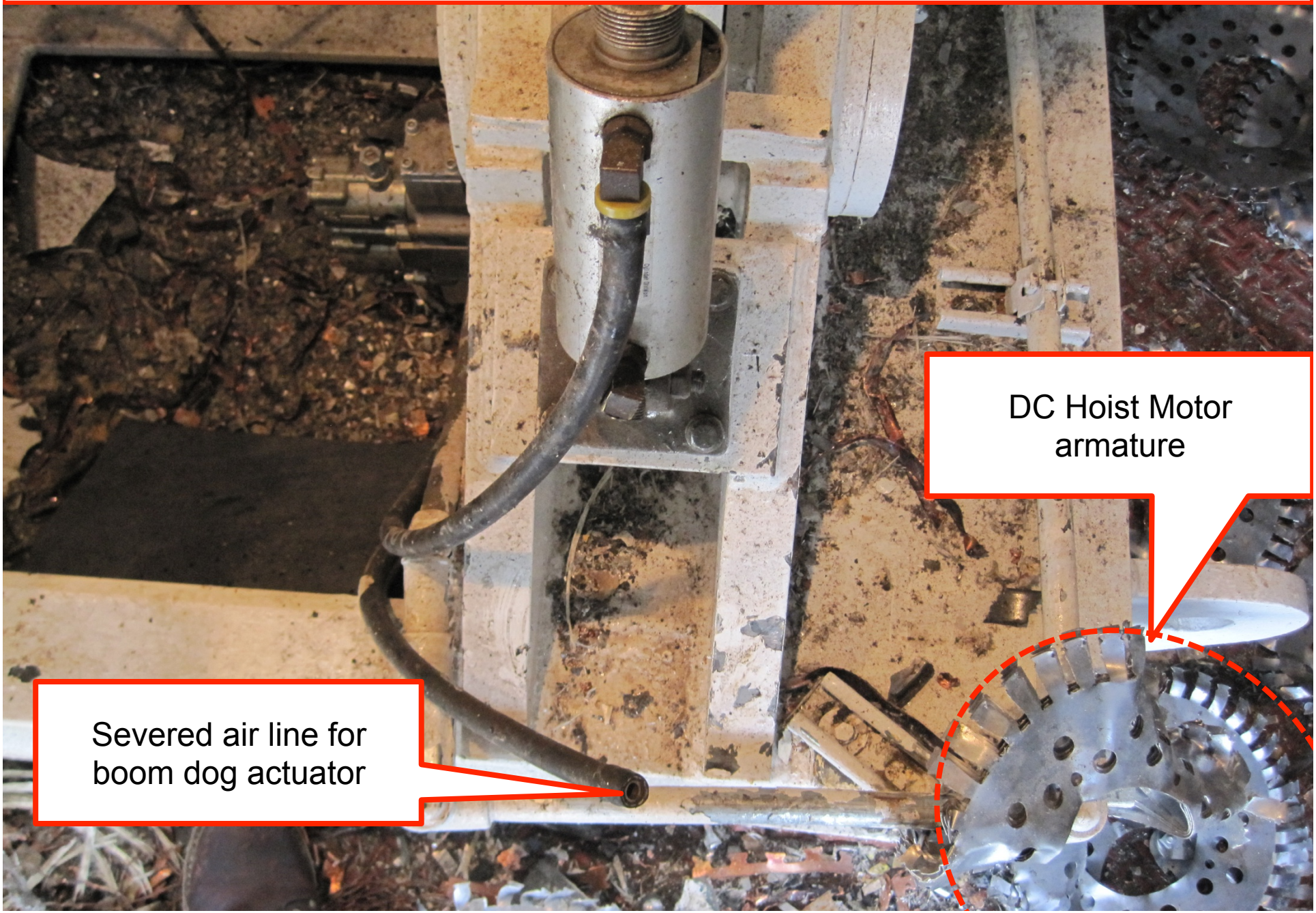


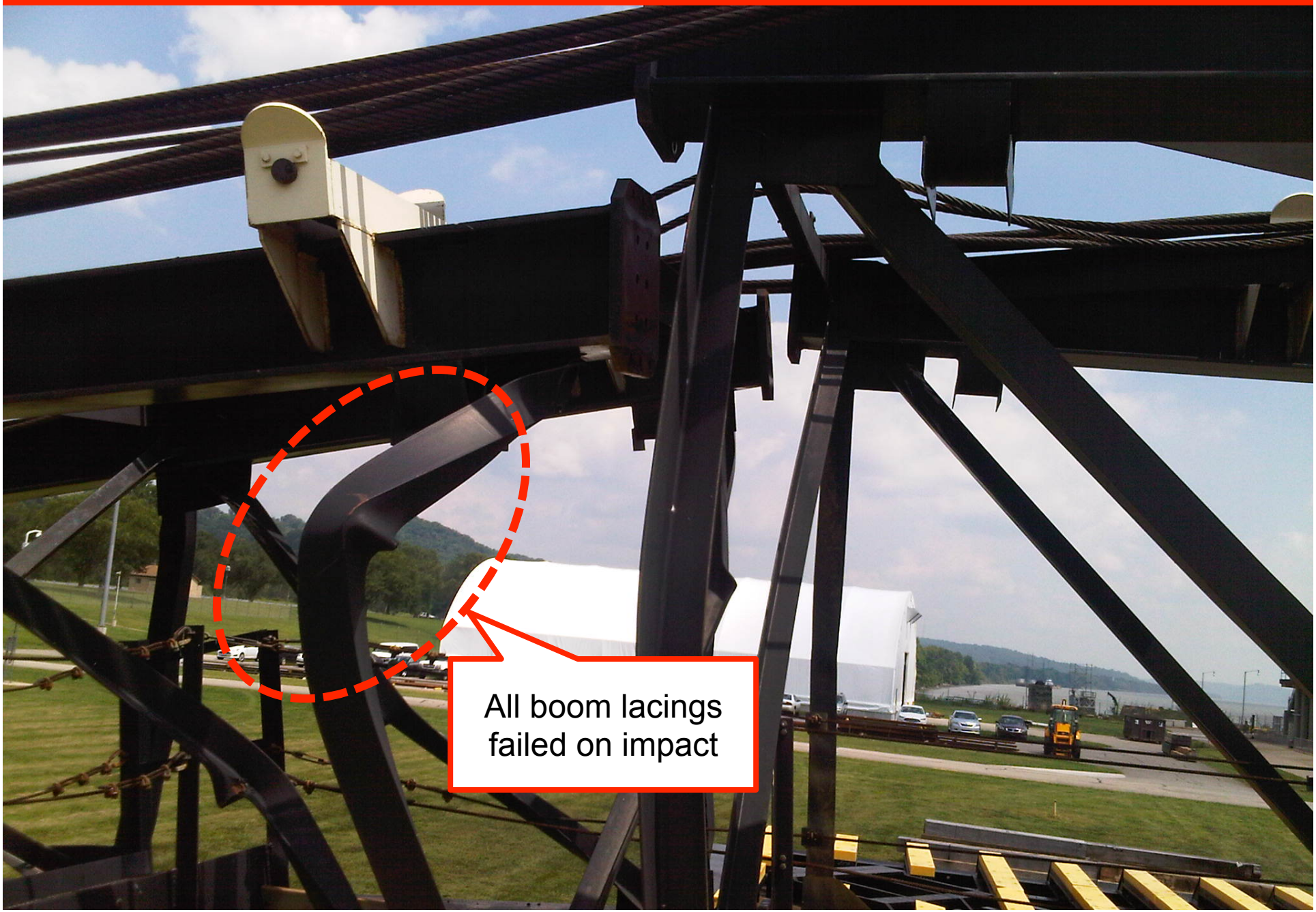
Disengaged Boom Dog

Failed Boom on Top of Miter Gate

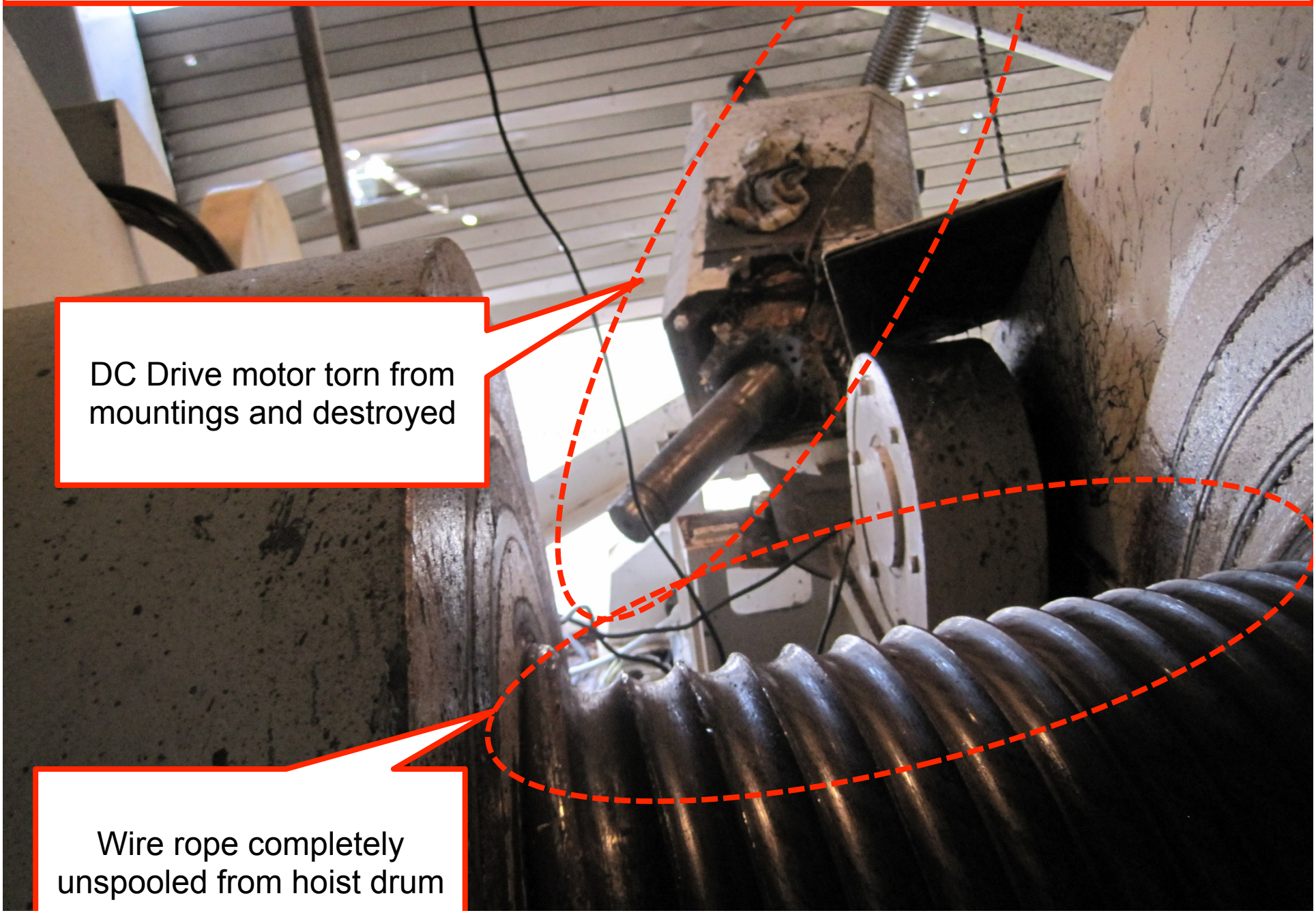
Failed Boom Tip Extending Past the Top of Miter Gate

Failed Boom Tip Connection

Failed Boom Tip Connection Close Up



Boom Hoist Machinery Damage



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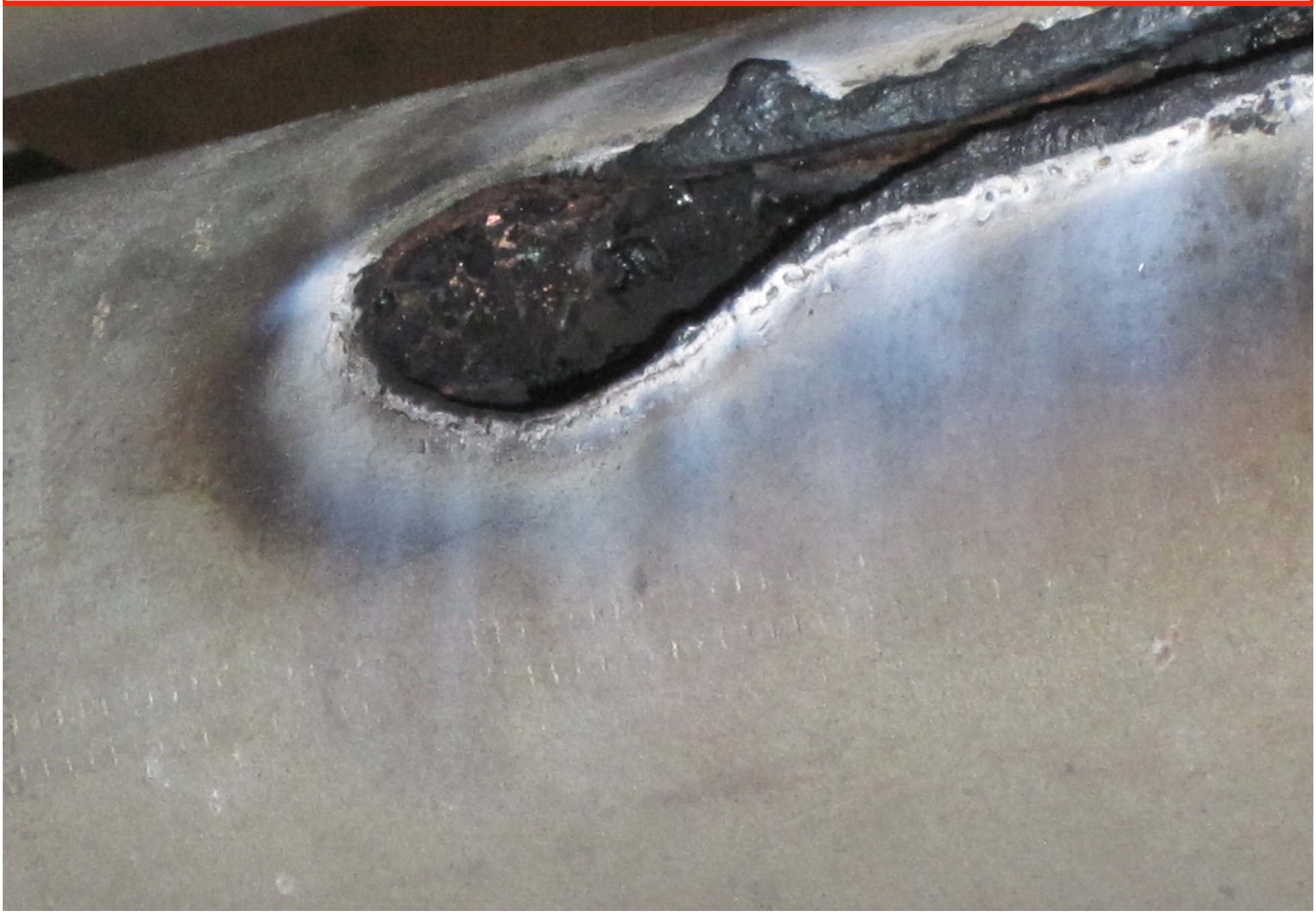
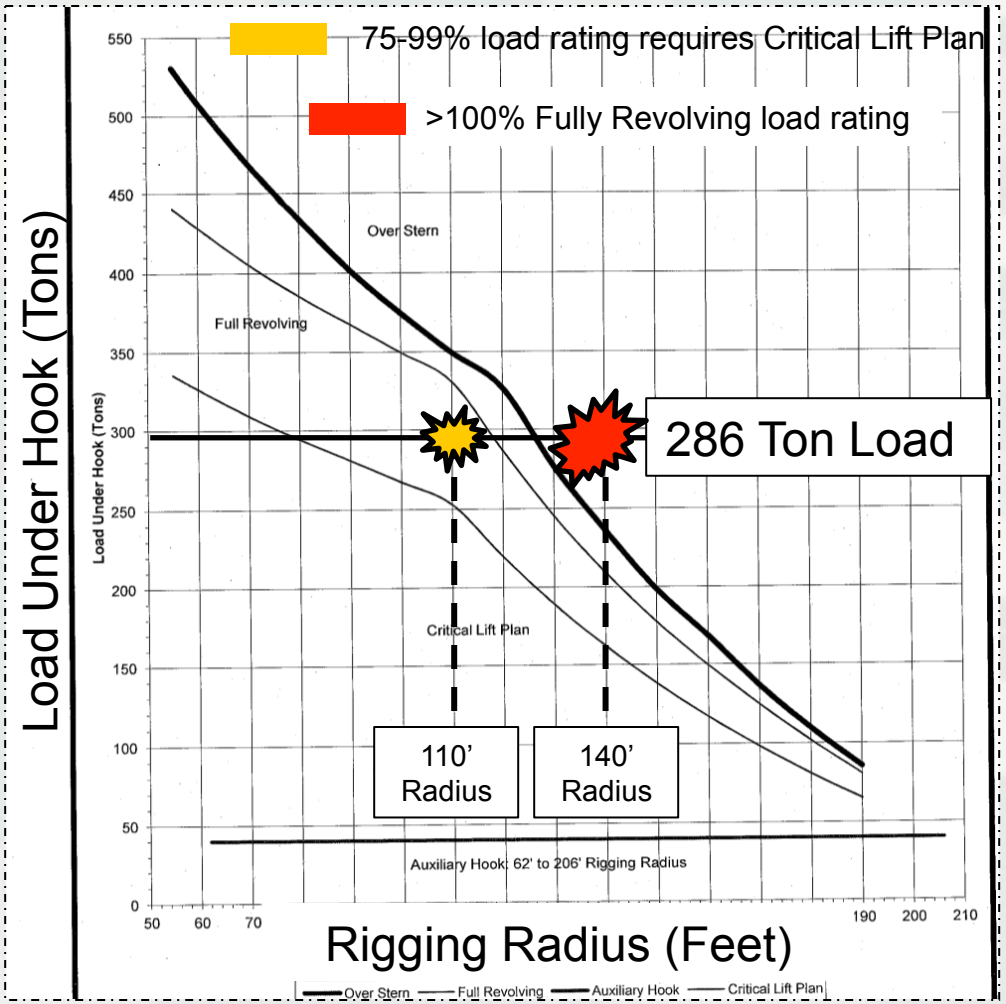


Markings for Gate Placement on the Esplanade

(original planned placement locations)

Operation Outside of the Load Chart



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