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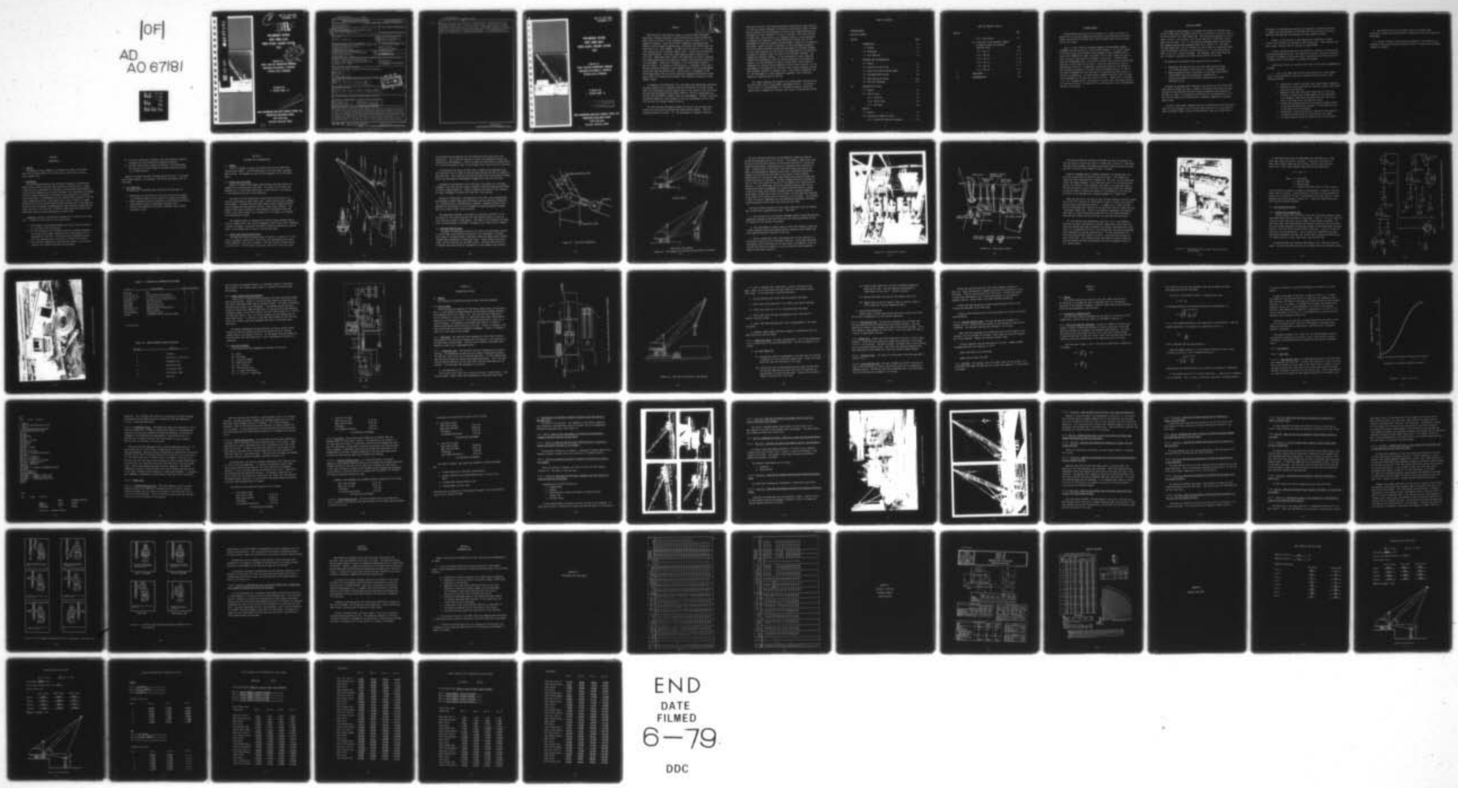

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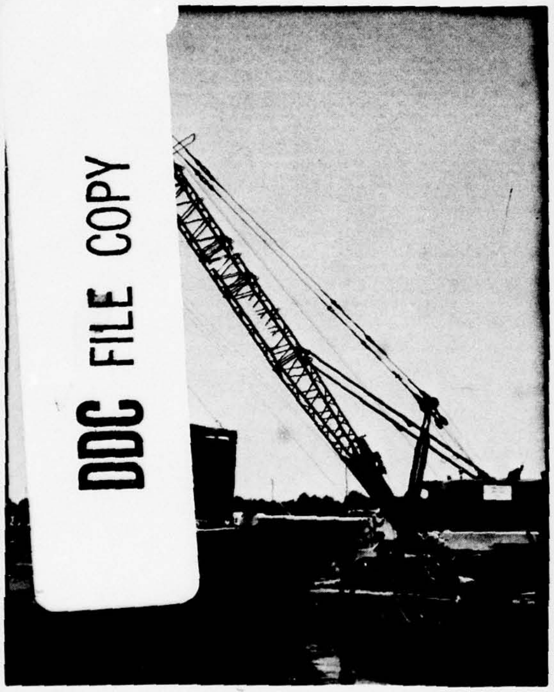

Prepared For
NAVAL FACILITIES ENGINEERING COMMAND
CONTAINER OFFLOADING & TRANSFER
SYSTEM (COTS) PROGRAM

Prepared By
J. DEXTER BIRD, III

EG&G WASHINGTON ANALYTICAL SERVICES CENTER, INC.
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Rockville, Maryland 20850

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The objectives of the Rider Block Tagline Test were to: demonstrate the feasibility of the rider block tagline concept as an effective means of load control in a dynamic environment; obtain engineering data for evaluation of the rider block tagline system (RBTS) design and operational characteristics; and evaluate the capability of the RBTS to enhance cargo operations at sea. The prototype RBTS was installed on a Bucyrus-Erie BE-38B crane and was tested under conditions of limited sea state. Of particular significance was the cont

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demonstration that the RBTS can be retrofitted on a standard commercially available, mobile crane. Stress in the boom due to ride loading, a major limiting factor in the use of cranes afloat, were significantly reduced by the RBTS as indicated by strain gage data, and the RBTS provided an increased level of load control in a dynamic environment. It is recommended that a full scale RBTS be built, installed and tested on a container capable crane.

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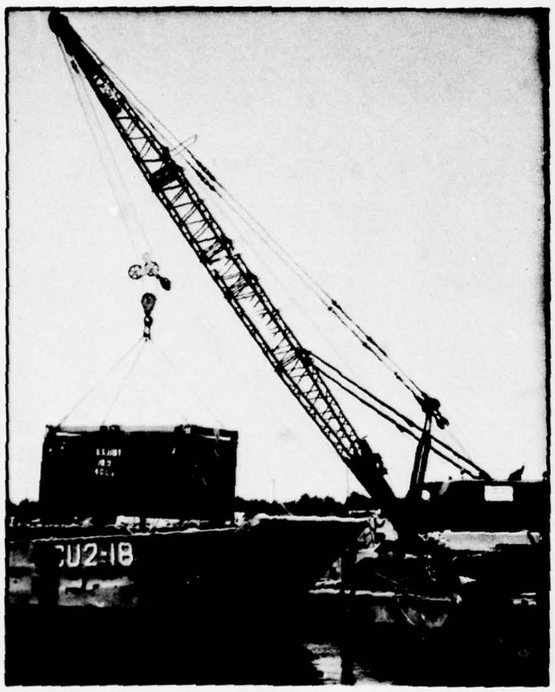

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PREFACE

DOD planning for the logistics support to sustain major contingency operations, including amphibious assault operations and Logistics-Over-the-Shore (LOTS) evolutions, relies extensively on the utilization of U. S. Flag commercial shipping. Since the mid 1960's commercial shipping has been steadily shifting towards containerships, Roll-on/Roll-off (RO-RO) ships and barge ships (e.g., LASH, SEABEE). By 1985 as much as 85% of U. S. Flag sealift capacity may be in container capable ships -- mainly non-selfsustaining (NSS) containerships. Such ships cannot operate without extensive port facilities. Amphibious assault and/or LOTS operations are usually conducted over undeveloped beaches and expeditious response times preclude conventional port development. Handling of containers in this environment presents a serious problem. The problem, as defined above, is addressed in the overall DOD Over-the-Shore Discharge of Cargo (OSDOC) efforts involving developments by the Army, Navy and Marine Corps. Guiding policy is documented in the "DOD Project Master Plan for Surface Container Supported Distribution System" and the OASD I&L system definition paper "Over-the-Shore Discharge of Cargo (OSDOC) System."

In response to the DOD Master Plan, Navy Operational Requirement (OR-YSL03) has been prepared for an integrated Container Offloading and Transfer System (COTS) for discharging container capable ships in the absence of port facilities. The COTS Navy Development Concept Paper (NDCP) No. YSL03 was promulgated July 1975 and the Navy Material Command tasked with development. The Naval Facilities Engineering Command has been assigned as Principal Development Activity (PDA) with the Naval Sea Systems Command assisting.

The COTS advanced development program includes the ship unloading subsystem, the ship-to-shore subsystem and common system elements. The ship unloading subsystem includes: (a) the development of Temporary Container

Discharge Facilities (TCDF) employing merchant ships and/or barges with add-on cranes and support equipment to offload non-selfsustaining (NSS) containerships alongside; (b) the development of Crane on Deck (COD) techniques and equipment for direct placement of cranes on the decks of NSS containerships to render them selfsustaining in an expedient manner; (c) the development of equipment and techniques to offload RO-RO ships offshore and (d) the development of interface equipment and techniques to enable ship discharge by helicopters (either existing or projected in other development programs). The ship-to-shore subsystem includes the development of elevated causeways to allow cargo handling over the surfline and development of self-propelled causeways to transport cargo from ships to the shoreside interface. The commonality subsystem includes: (a) the development of wave attenuating Tethered Float Breakwaters (TFB) to provide protection to COTS operating elements; (b) the development of special cranes and/or crane systems to compensate for container motion experienced during afloat handling; (c) the development of transportability interface items to enable essential outsize COTS equipment transport on merchant ships -- particularly bargeships, and (d) the development of system integration components such as moorings, fendering, communications and services.

This report addresses the progress and accomplishments associated with the Rider Block Tagline System (RBTS) development efforts. The objective of this effort is the development of a hardware package to improve the capabilities of commercially available land cranes in offshore applications.

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ACKNOWLEDGEMENT

EG&G Washington Analytical Services Center, Inc. wishes to express its appreciation to the many commands and individuals who contributed to the development and testing of the Rider Block Tagline System (RBTS) and the preparation of this report.

The U. S. Army's Mobility Equipment Research and Development Command (MERADCOM) provided the BE-38 B crane and RBTS hardware. Mr. Clifton Stevens of the David Taylor Naval Research and Development Center (DTNSRDC) and Mr. Frank Stora (MERADCOM) followed the project from its early stages and were on hand to assist in the solution of problems as they arose. The Naval Beach Group TWO (NAVBEACHGRU TWO), Little Creek, provided the facilities and personnel necessary for the harbor and sea tests. Particular appreciation is due to EQCM Gannon and EO2 Hill of Amphibious Construction Battalion TWO (PHIBCB 2), who followed the progress of the RBTS from the acceptance test at Ft. Belvior and whose recommendations were invaluable in integrating the RBTS controls to improve its operability. The Naval Coastal Systems Laboratory (NCSL) provided the instrumentation and data acquisition facilities. Appreciation is extended to Mr. Bill Culpepper and Mr. Jim Shelton of NCSL for their assistance throughout the test and to Mr. Jim Sandlin for his contributions to the instrumentation portion of this report.

EXECUTIVE SUMMARY

The purpose of this document is to present the results of the Rider Block Tagline System (RBTS) Development Test DT-IIE as delineated in the COTS Test and Evaluation Master Plan (TEMP) Number 299. The testing was conducted at Little Creek, Virginia, during October 1977 and was comprised of land tests, harbor tests, and sea tests. The U. S. Army Mobility Equipment Research and Development Command conducted the acceptance tests at Ft. Belvoir, Va. The crane was then loaded onto a LCU for transport to Little Creek, Va. where Naval Beach Group TWO personnel installed it on the center of a 4 x 10 NL pontoon barge which is part of a 3 section causeway. The Commander, Naval Beach Group TWO was in charge of conducting the harbor and sea portion of the test.

The objectives of the Rider Block Tagline DT-IIE Test were to:

a. Demonstrate the feasibility of the rider block tagline concept as an effective means of load control in a dynamic environment.
b. Obtain engineering data for evaluation of the Rider Block Tagline System (RBTS) design and operational characteristics.
c. Evaluate the capability of the RBTS to enhance cargo transfer operations at sea.

Although the prototype RBTS installed on the BE 38-B was only tested under conditions of limited sea state, a number of conclusions were drawn from both the data and the experience resulting from the preparation and execution of the test as a whole. Of particular significance was the demonstration of the fact that the RBTS can be retrofitted to a standard, commercially available, mobile crane.

In spite of the control problems, peculiar to the design of the crane available for this prototype, and the limited indoctrination of the cargo handling crew to the RBTS concept, test data indicated that there was no significant difference in cargo handling productivity as compared to non-RBTS operations. It appears that the performance of the RBTS would be significantly improved when the crane operators and signalmen are given adequate training.

Stresses in the boom due to side loading were significantly reduced by the use of the RBTS, as indicated by strain guage data. These stresses have been a major limiting factor in the use of cranes afloat.

Finally, the RBTS proved to be very helpful in the task of replacing the LASH barge hatchcovers at sea. This operation, because of the close tolerances involved in alignment of the mating parts, indicated that the RBTS provided an increased level of load control in a dynamic environment.

Based on the results of the RBTS DT-IIE test, the following recommendations are made.

1. A full scale RBTS should be built and installed on a COTS capable crane. During the design of this unit, attention should be given to the following features:

a. Integration of control functions from a human factors standpoint.
b. Selection of a winch unit that will provide a smooth, controllable actuation of the taglines.
c. Redesign of the rider block and/or hook block to allow "two blocking" of these units without damage, and the development of an automatic rider block line hoist that will take up the slack in the rider block line when this occurs.
d. Elevate the attachment points of the tagline outrigger sheaves to increase the operational envelope, if lifts above the level of the crane are to be performed.
e. Incorporate a rider block position indicator or other means of providing the operator with an indication of load radius.
f. An audible warning system for excess tension in the taglines.

2. The testing of the full scale RBTS should be conducted under conditions of significant relative motion as described in the COTS operational requirement.

3. A formal training program should be conducted for the operators and signalmen in how to make the most effective use of the features and advantages inherent in the RBTS.

SECTION I

INTRODUCTION

1.1 PURPOSE.

The purpose of this document is to present the results of the Rider Block Tagline System (RBTS) DT-IIE Test held at Little Creek, Virginia, during October 1977.

1.2 BACKGROUND.

The joint Army/Navy/Marine Corps Off-Shore Discharge of Containership (OSDOC) Test/Evaluation exercises were conducted in 1970 and 1972 in order to explore various techniques for unloading a containership moored offshore using available commercial and military equipment in an operational environment. A primary problem encountered in the test was the difficulty of accurately placing containers in lighterage due to the uncontrollable swinging of the container (pendulation) from a crane operating on a ship or barge in a seaway. The Rider Block Tagline System (RBTS) has been developed as a viable means of minimizing the sea induced load pendulations, more accurately controlling the radial position of the load with a minimum of boom luffing and reducing the potentially high side loads experienced by cranes afloat.

Acceptance testing of the RBTS was conducted at Ft. Belvoir on 2-3 June 1977. A summary of the results of this test follows:

a) The kinematic relationships between the various lines were checked out and found to be satisfactory.

b) All winch drums and their respective controls performed adequately, except the tagline payout system which was unacceptable for the requirements of the RBTS. Modifications were implemented shortly after the acceptance test to partially alleviate this problem.

c) All structural components of the RBTS were loaded, to verify their integrity and freedom from manufacturing defects.

d) The static operational envelopes, which were observed, compared favorably with those predicted by computer simulation.

e) The RBTS significantly reduced the stresses in the boom chords and lacings due to side loading of the boom caused by operating in a listed condition.

Appendix A presents the data collected during this test. It includes strain guage readings, line tensions, rider block coordinates, and list conditions.

1.3 TEST OBJECTIVES.

The objectives of the Rider Block Tagline DT-IIE Test were to:

a. Demonstrate the feasibility of the rider block tagline concept as an effective means of load control in a dynamic environment.

b. Obtain engineering data for evaluation of the Rider Block Tagline System (RBTS) design and operational characteristics.

c. Evaluate the capability of the RBTS to enhance cargo transfer operations at sea.

SECTION II

EQUIPMENT AND INSTRUMENTATION

2.1 GENERAL.

Figure 2-1 presents a Bucyrus Erie 38-B crane with the Rider Block Tagline System (RBTS). The Army owned Bucyrus Erie 38-B, RBTS, equipment modifications, instrumentation, and auxiliary equipment will be discussed below.

2.2 BUCYRUS ERIE 38-B CRANE.

Appendix B presents the standard specifications and load ratings of a commercially available Bucyrus Erie 38-B. The crane, for this test, was equipped with a 70 foot boom consisting of a base section, a tip section, a 5 foot extension and two 10 foot extensions.

The crane is of the conventional crawler design consisting of a revolving superstructure, diesel power plant, crawler base and mast suspended boom assembly. The power from the diesel engine passes through the master clutch, engaged from the operators console, to the torque convertor. The output of the torque convertor is then directed to the desired functions (hoist, boom, swing, propel, etc.) by means of air clutches, also actuated from the operators console.

The standard machine is equipped with two hoist drums, mounted side by side on a common shaft, that can be independently controlled by their respective clutches and brakes. An optional third drum, primarily designed as a utility winch, can be mounted just in front of the two main drums.

2.3 RIDER BLOCK TAGLINE SYSTEM (RBTS).

The Rider Block Tagline System, shown in Figure 2-1, consists of a rider block, outriggers, tagline and a rider block line supplementing the conventional commercial lift crane's hardware. The load lines are reeved through the rider block. The horizontal and vertical positions of the rider block

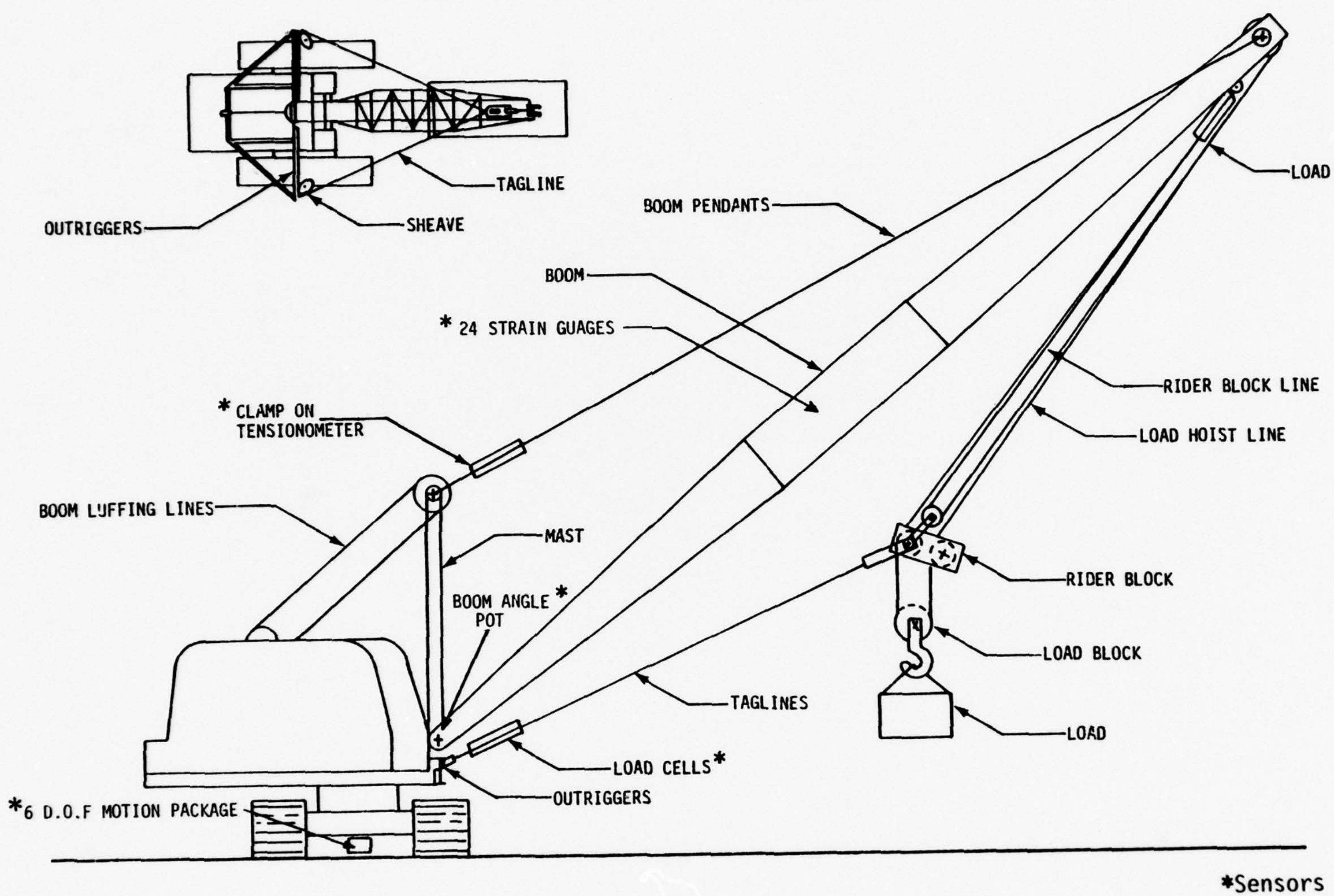


Figure 2-1. Bucyrus Erie 38B with Rider Block Tagline System

are controlled by the operator with the taglines and the rider block line, respectively. This allows the operator to control the pendulation length and load position simultaneously. Figure 2-2 shows the rider block in greater detail. It is fully articulated so that it can conform to the line of action of each wire.

As installed on the 38-B, the load line is reeved on the right main drum, the rider block line is reeved on the left drum, and the taglines are reeved on the third drum. This allows the load and the rider block to be raised at approximately the same speed by simultaneously engaging the right and left drum.

Actuation of the taglines or the rider block line results in a nonlinear response of the load that may require a degree of operator/signalman proficiency to insure a smooth operation. Figure 2-3 depicts the nature of this response for equal increments of tagline and rider block line position.

Because of limitations in the capacities of the 38-B, this prototype RBTS was designed to handle 5000 pound palletized cargo and LASH barge hatchcovers in a limited portion of the operational envelope. Although not specifically designed for the purpose, it is also capable of handling container spreader bars and an empty 20 foot MILVAN container.

The operational envelope, of the RBTS as installed on the 38-B, is the collection of rider block positions such that neither tagline is slack nor has a tension in excess of 3000 pounds. The width of this envelope, and therefore, the effectiveness of the RBTS, increases as the rider block is lowered.

2.4 EQUIPMENT MODIFICATIONS.

Throughout the acceptance testing at Ft. Belvoir and preliminary testing at Little Creek, major attention was given to the improvement of the RBTS with respect to hardware design, operational safety and human factors aspects. Problems were encountered in three major areas - those related to the basic crane, the test platform, and the RBTS concept. The major modification requirements were precipitated by inadequacies of the standard crane controls.

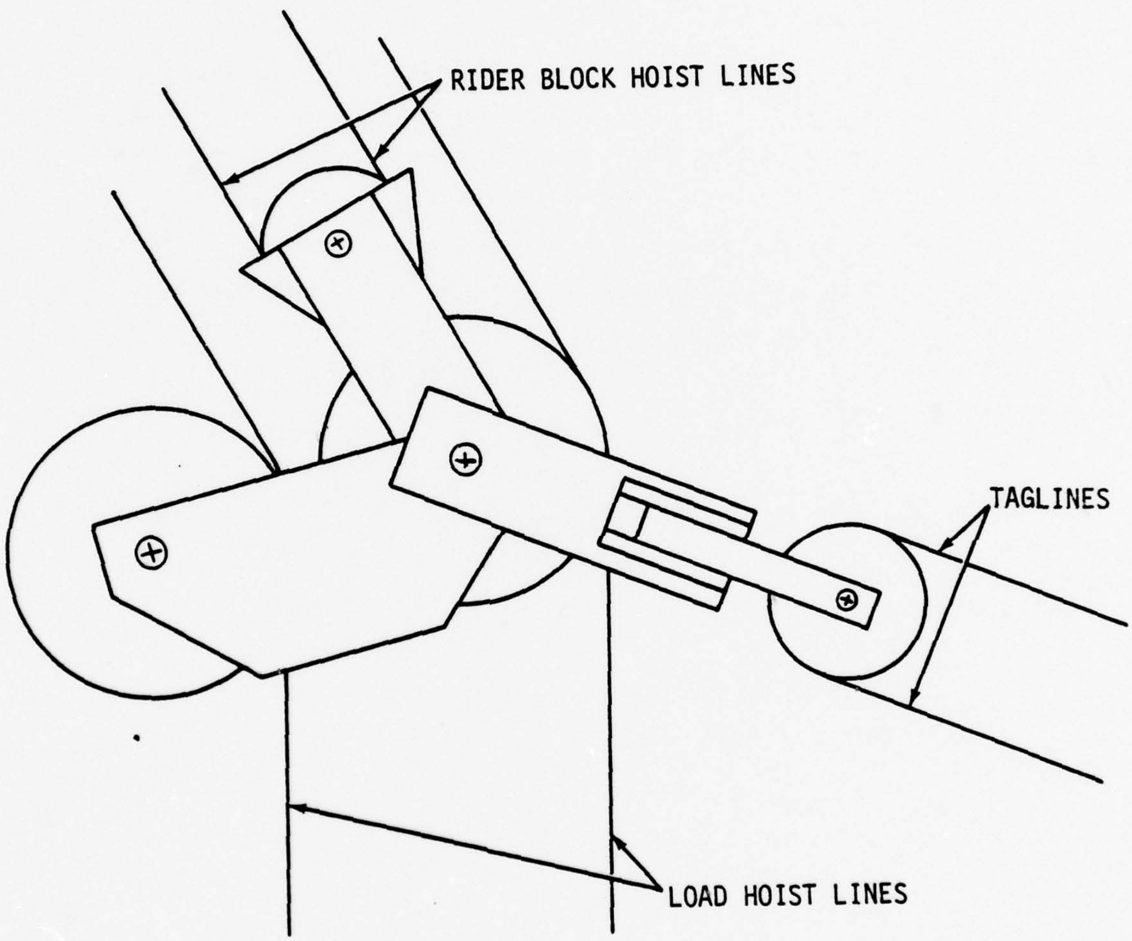
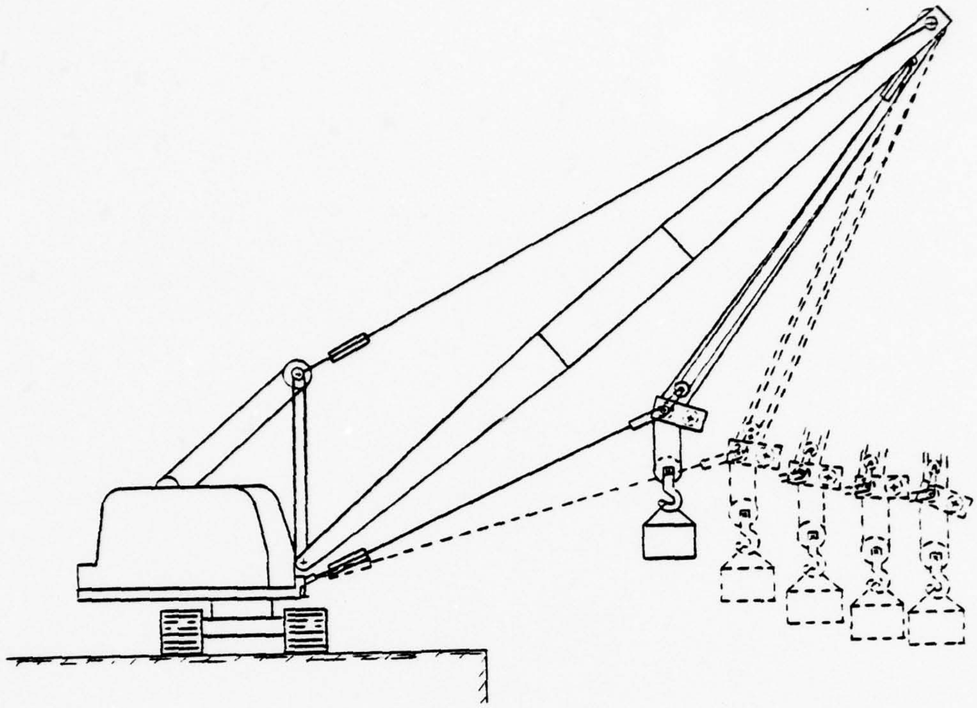
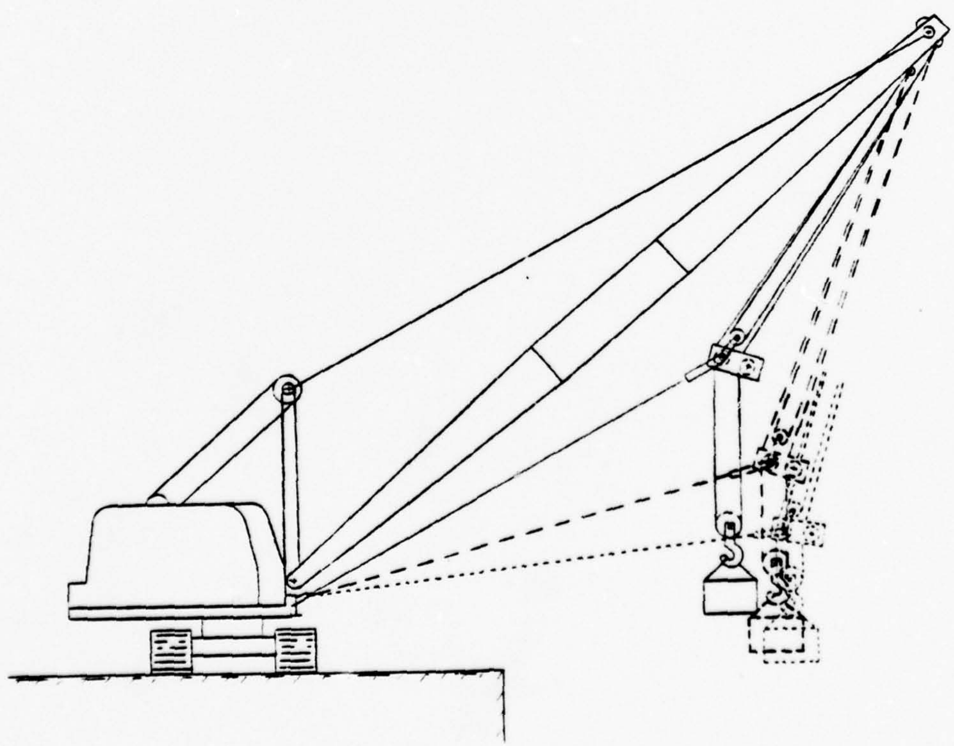


Figure 2-2. Rider Block Components



Tagline Control



Rider Block Line Control

Figure 2-3. Load Response to Tagline and Rider Block Line Control

The first and major deficiency of the mechanical system was observed during the acceptance tests at Ft. Belvoir. The standard, commercially available third drum that was selected for the tagline winch was of a relatively unsophisticated design, incorporating an air actuated clutch and brake release. Forward motion of the control lever would release the spring set brake, and simultaneously engage the cross shaft clutch which mechanically connects the third drum to the output of the crane's torque convertor. Reverse motion of the control lever would release the spring set brake only, allowing the drum to free wheel. The major drawback with this system was a lack of "feel" and control on the part of the operator while paying out the taglines. It was determined, during the acceptance testing, that the air release brake should be augmented by a manually operated hydraulic system. A relatively simple brake release, designed around a standard automotive brake master cylinder and clutch slave cylinder, was fabricated and installed on the crane at Ft. Belvoir prior to transport to Little Creek. This provided a "feel" and control comparable with the conventional mechanical foot brake lowering system utilized on the rider block and load lines.

During preliminary testing at Little Creek, additional areas for improvement of the overall operation were noted. These were:

a. The low position of the tagline crossbeam greatly limited the effective operational envelope of the rider block over the LASH barge without fouling the taglines on the coaming of the barge.

b. The large number of control levers on the crane required a great deal of hand changing during cargo handling cycles, producing a more complex and time consuming operation (Figures 2-4 and 2-5).

c. With a conventional crane, the operator has a direct indication of load radius by the use of his boom angle indicator. During RBTS operations, the operator had no indication of the load radius, and therefore, could not position the load while swinging, as could be done with the conventional crane and boom angle indicator.

Figure 2-4. Crane Control Console

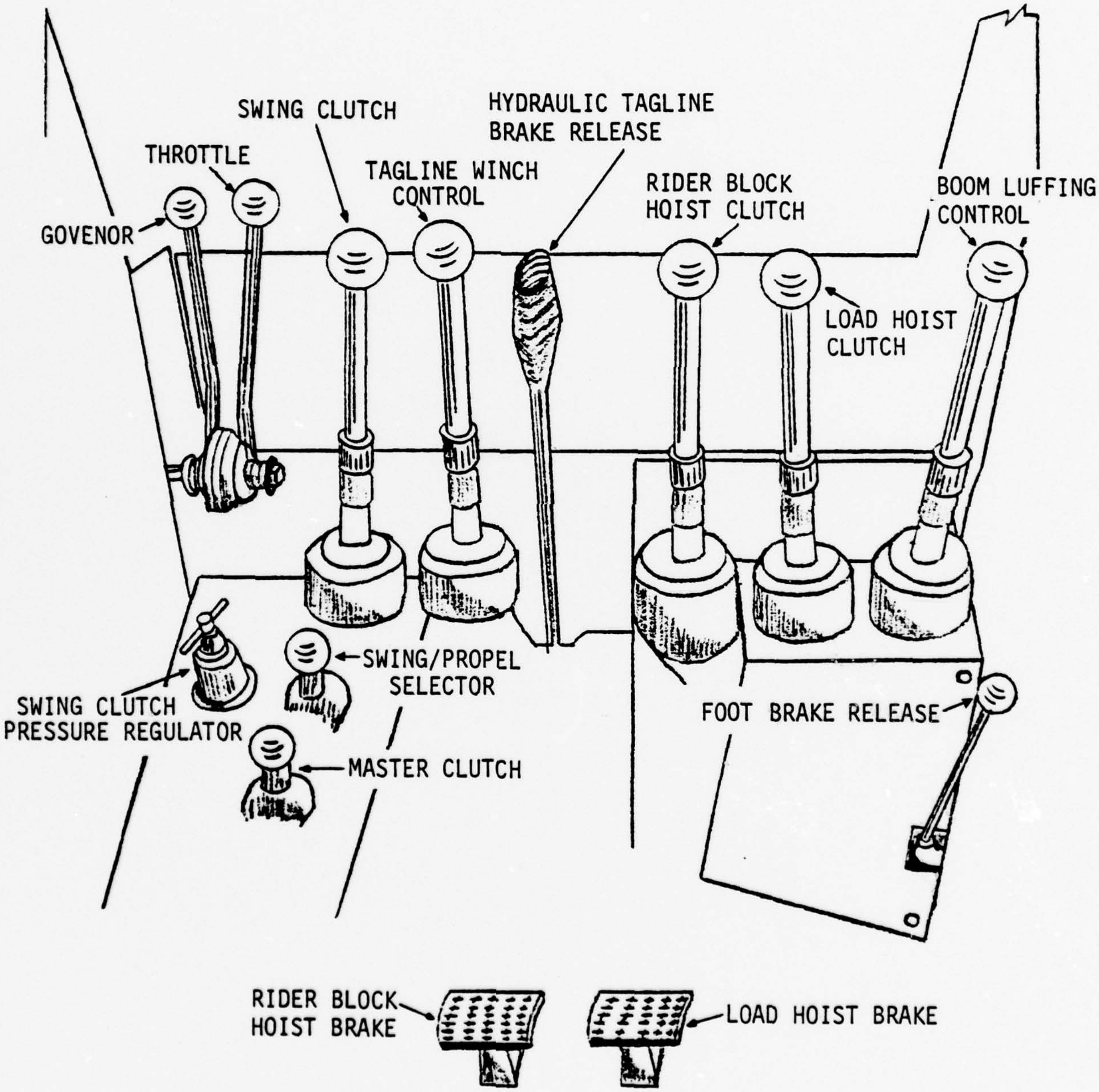


Figure 2-5. Crane Control Details

The useful operational envelope of the RBTS was greatly increased over the LASH barge by placing the crane on 4 timber mats, raising it 2 feet above the deck of the causeway, and fendering the barge 5 feet away from the causeway with three foam filled fenders (5 feet x 10 feet).

Based on recommendations by PHIBCB-2 personnel, the tagline hoist control was incorporated with the main load hoist lever. The standard air controllers have three positions - forward, aft, and port. On this particular crane, the forward movement is for load hoist, port is for the warning horn, and the aft position is not connected since there is no power down option. The horn was moved to the aft position, and the tagline winch was connected to the port motion, allowing the operator to simultaneously raise the load and bring in the taglines with a diagonal movement of a single lever.

Both the rider block line and the load line were lowered by the foot brakes, but it was still necessary to change hands in order to release the hydraulic tagline brake system described earlier. To remedy this, a power assisted bicycle brake handle was installed on the load hoist lever to release the tagline brakes (Figure 2-6). With this successfully implemented, the operator could work in a more conventional manner with his right hand dedicated to boom and hoist control and the left hand for swing and throttle control.

All line tensions were monitored by load cells, but it was deemed undesirable to require the operator to monitor these meters during operation. Since the taglines were most vulnerable to accidental overloading that might result in a catastrophic failure, it was decided that they should be equipped with a mechanically actuated, audible alarm. This was accomplished with two Dillon dyna switches, wired in parallel, to activate the existing air horn on the crane. This provided an easy and effective warning system for both the operator and the cargo handlers, who were accustomed to the horn as a warning signal.

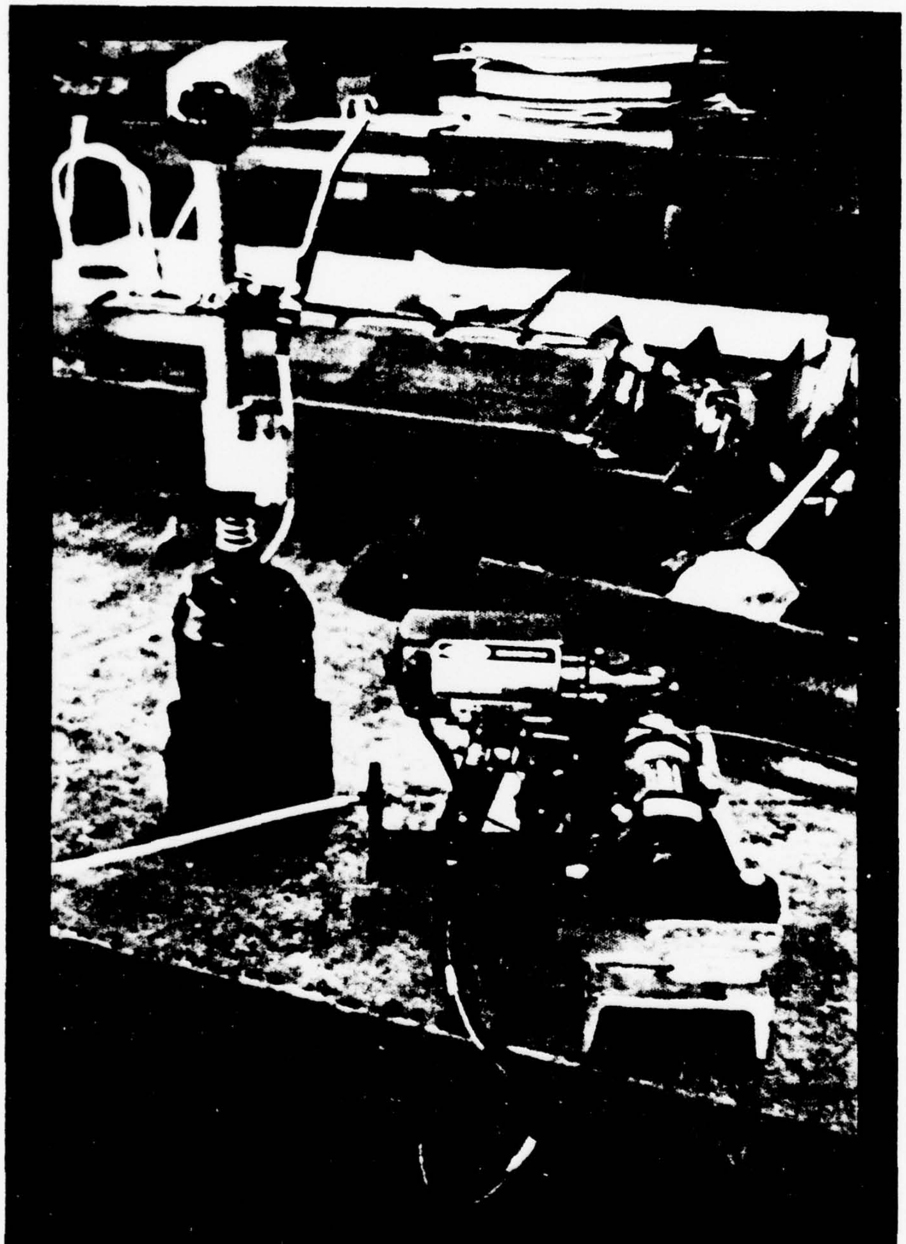


Figure 2-6. Prototype Testing of Power Assisted Tagline Brake Release

A final modification was the development and installation of a rider block load radius and position indicator. It basically consisted of a three wheel footage counter on the taglines, a tagline angle measuring device, and a small analog computer that performs the computation:

$$R = L \cos \Theta + C$$

where R = load radius
L = tagline length
Θ = tagline angle
C = distance from cross beam to ℄ crane rotation.

This was used as an output to a meter in the operator's cab where it could be easily seen at a glance. A minor addition to the basic circuit provided the ability to calculate the "X" and "Y" coordinate of the rider block for instrumentation and testing purposes (Figure 2-7). Figure 2-8 presents the rider block position indicator hardware.

2.5 DATA ACQUISITION SYSTEM.

2.5.1 SENSORS AND INSTRUMENTATION.

Various sensors were installed on the crane, and during testing, signals from these sensors were recorded on analog tape. Table 2-1 lists the number and location of each type sensor and the number of data channels recorded. The Wave Rider Buoy, Time Code Generator and Intercom signals were not multiplexed, but were recorded separately on dedicated channels of the analog tape recorders. Table 2-2 lists the analog recorder channel allocation. Figure 2-1 shows the location of the various sensors. The six degree-of-freedom motion package was mounted underneath the crane cab, and was used to measure platform motion. Its outputs are roll, pitch, surge, heave, sway and yaw rate.

The Wave Rider Buoy was tethered approximately 150 to 200 yards from the barge. The Wave Rider Buoy Receiver was installed inside the Instrument Shelter,

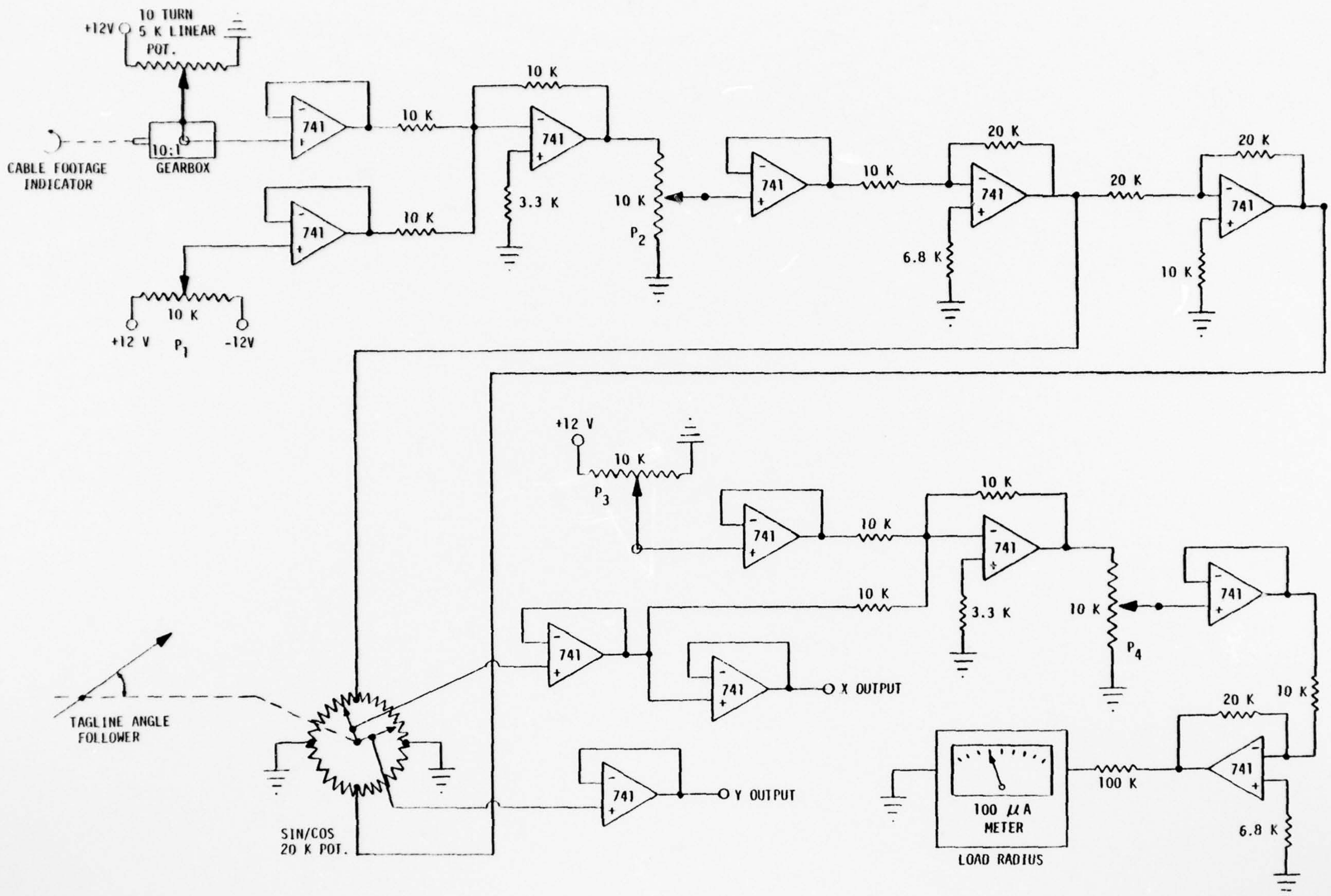


Figure 2-7. Schematic of the Rider Block Load Radius and Position Indicator

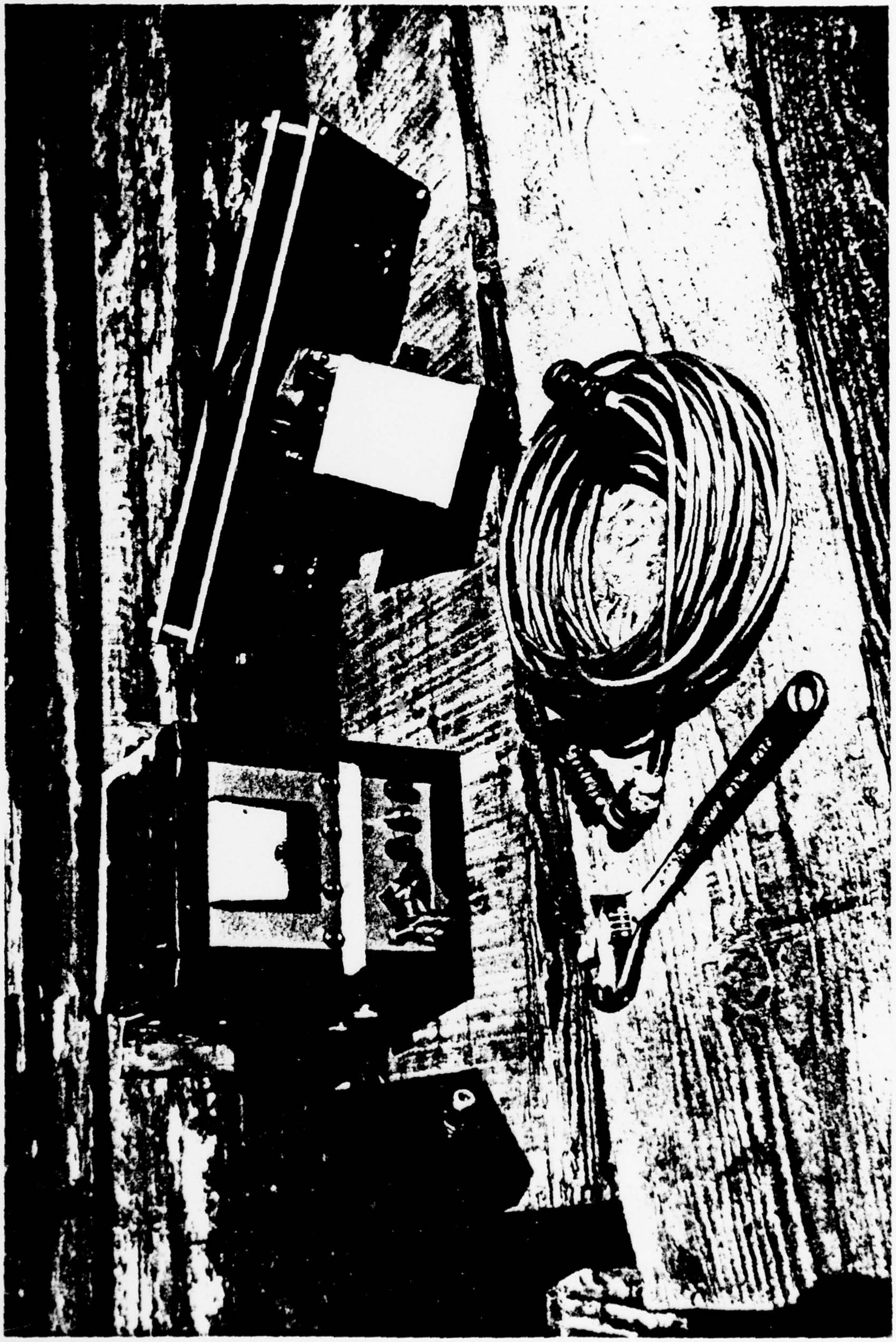


Figure 2-8. Rider Block Position Indicator Hardware

TABLE 2-1. SENSORS AND INSTRUMENTATION RECORDED

TYPE	LOCATION/FUNCTION	NUMBER	DATA CHANNELS
STRAIN GAGE	Boom	24	24
Dillon Load Cell, 5K	One on the dead end of each tagline	2	2
Dillon Load Cell, 10K	On the dead end of the rider block line	1	1
Tensionometer, 40K	On the boom luffing line and the load line	2	2
Potentiometer	Boom Foot (Boom Angle)	1	1
Potentiometer	Rider Block Position (x)	1	1
Potentiometer	Rider Block Position (y)	1	1
Motion Sensor, 6 DOF	Underneath Crane Cab (Platform Motion)	1	6
Wave Rider Buoy*	Seaway (Sea State)	1	1
Time Code Generator*	Instrumentation Shelter	1	1
Intercom*	Instrumentation shelter, Crane Cab and Remote	1	1

* - Not Multiplexed.

TABLE 2-2. ANALOG RECORDER CHANNEL ALLOCATION

CH. NO.	Function
1	Intercom
2	IRIG-B Serial Time Code
3	Tachometer Sync
4	Wave Rider Buoy
5	PCM Encoder, DMM
6	PCM Encoder, NRZL
7	Not Used

and its output was recorded directly on a dedicated channel of the analog tape recorder. The recorder output signal is a measure of wave amplitude and frequency.

2.5.2 SIGNAL CONDITIONING AND RECORDING.

Figure 2-9 is a simplified block diagram of the data acquisition system used during the RBTS. Outputs of the thirty-eight sensors are applied to the two signal conditioners where they are properly scaled. The signal conditioners provide analog signals to the PCM Encoder. This encoder outputs two serial streams of digital data (NRZL and DMM) from a 75 Ohm source for tape recording. The encoder samples the 38 data channels (plus 26 unused channels) at a rate of 250 times each second. Thus, the 38 data channels are multiplexed onto two analog tape tracks. In addition, on the same tape recorder are one time code track, one intercom track, one tachometer sync track, and one Wave Rider Buoy track.

The Encoder Decommutator and Demultiplexer are used to extract analog signals from the data stream coming from the encoder by way of the tape recorder monitor and playback circuitry. As the outputs from the Encoder are being recorded, real-time analog data is thus simultaneously available for inspection.

2.6 AUXILIARY EQUIPMENT.

The following auxiliary equipment was required for the test:

(a) LCM-8
(b) LASH Barge
(c) 3 section causeway
(d) Single point moor
(e) LCU - tow boat
(f) 2 Mike-6 work boats
(g) 3 - foam filled fenders
(h) 4 - (5'x16'x1') Timber Mats

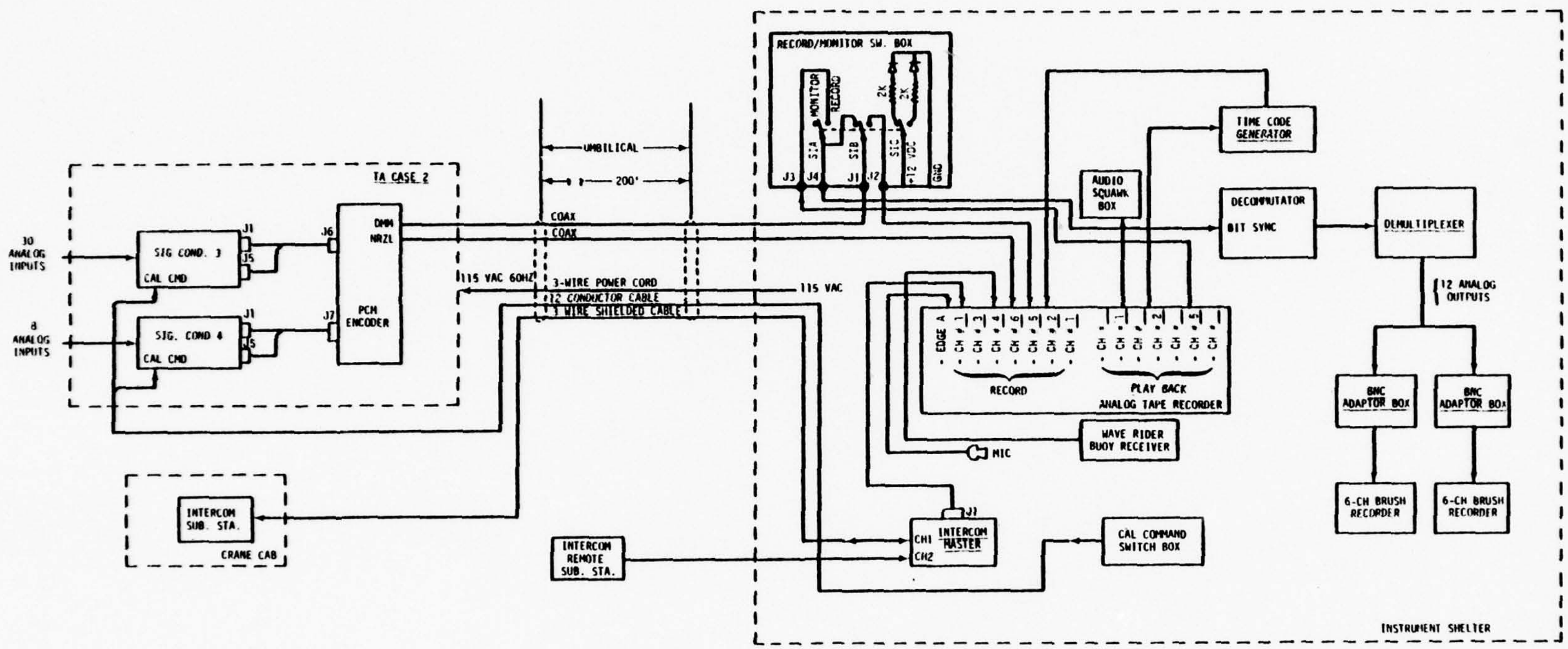


Figure 2-9. Wiring Diagram of Crane Test Instrumentation

SECTION III

DESCRIPTION OF TESTS

3.1 GENERAL.

This section will describe the type of tests that were conducted.

3.2 TYPE OF TESTS.

The DT-IIE test was comprised of land tests, harbor tests, and sea tests. The U. S. Army Mobility Equipment Research and Development Command conducted the acceptance tests at Ft. Belvoir, Va. The crane was then loaded onto a LCU for transport to Little Creek, Va. where Naval Beach Group TWO personnel installed it on the center of a 4 x 10 NL pontoon barge which is part of a 3 section causeway. The Commander, Naval Beach Group TWO was in charge of conducting the harbor and sea portion of the test. Figure 3-1 presents a plan view of the harbor and sea test equipment arrangement. Figure 3-2 presents a side view of the crane on the causeway.

3.2.1 LAND TESTS. The land tests were conducted at Little Creek, Virginia. The purpose of the tests was to expose the crane operator to the operation of the Rider Block Tagline System. The land tests included a functional test, pendulation tests, and a jeep handling test.

3.2.1.1 Functional Test. The functional test was conducted with no load on the hook. Its purpose was to check out the kinematic relationships between the taglines, rider block, hoist lines and boom angle. The test demonstrated that the crane winches and controls were operating properly. Also, this test familiarized the operator with the rider block tagline system operation and controls. The functional test procedure is as follows:

a. Set boom angle at 45°

Slack tagline until load line is vertical and hook is approximately 1 foot off the ground. Adjust rider block approximately 3 feet above hook block.

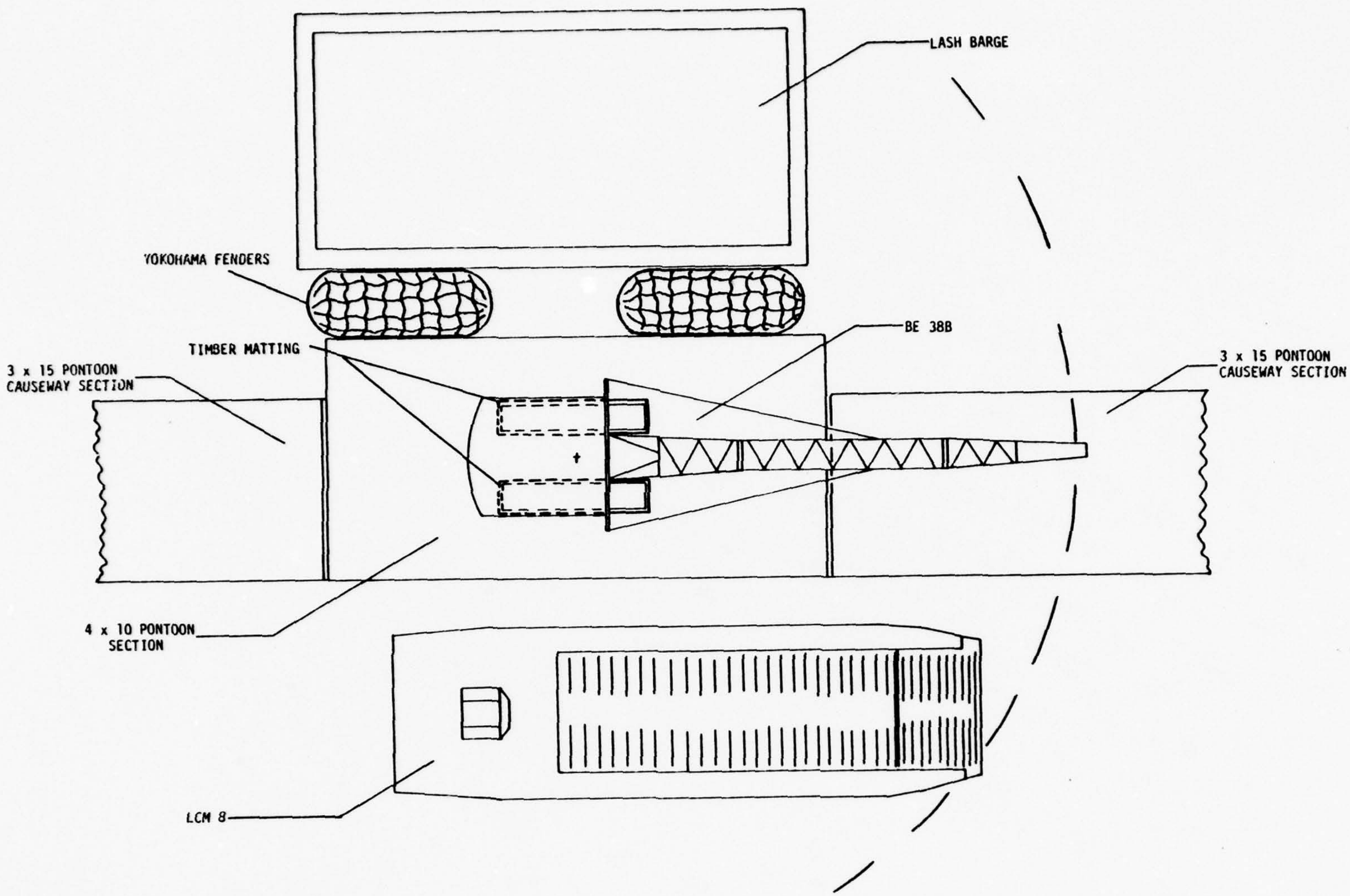


Figure 3-1. Plan View of the Harbor and Sea Test Equipment Arrangement

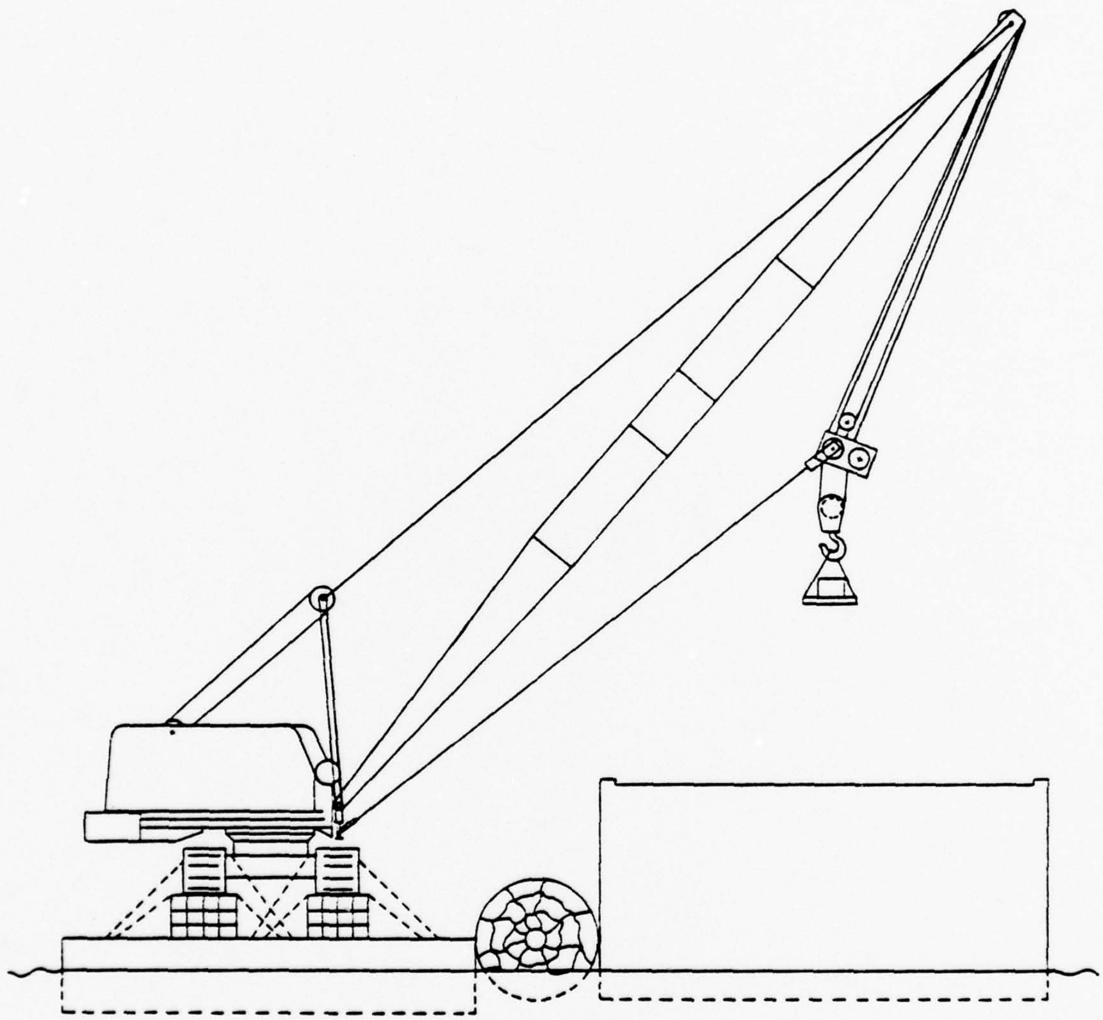


Figure 3-2. Side View of the Crane on the Causeway

b. Winch in taglines until rider block is within a few feet of the boom. (Note: At no time during this test should any line tensions exceed 5000 pounds. If this does occur, terminate operation).

c. Pay out taglines until hoist lines are vertical once again.

d. Hoist rider block alone until it is within a few feet of the boom.

e. Lower rider block until it is 3 feet above hook once again.

f. Hoist rider block and hook simultaneously until rider block is within a few feet of boom.

g. Lower rider block and hook until hook is approximately 1 foot above the ground.

h. Operator should repeat the above movements or combinations until he gains familarity with the system.

3.2.1.2 Pendulation Tests. The tests conducted were: (a) off-lead pendulation (i.e., in plane) and (b) out-of-plane pendulation. The test procedures are as follows:

a. OFF-LEAD PENDULATION

(1) Relocate the crane at an embarkment on the pier that will provide a clearance of 8 to 10 feet below ground level. Attach the 10,000 pound test load with the boom at a 45° angle.

(2) Position the load at approximately 24 feet beyond the boom base. Pay out the rider block and load lines until the taglines are approximately 10° below the horizontal. Adjust the load approximately 5 feet below the rider block.

(3) Attach a hand rachet hoist and quick disconnect between the crane and the load. Pull the load back approximately 8° (1500 pounds on hand hoist). Release disconnect.

(4) Record rider block line and tag line tensions (max, min).

(5) Repeat steps (3) and (4) several times for various values of initial position, load and pendulation angle.

b. OUT-OF-PLANE PENDULATION

Conduct tests as above except attach hand hoist so that initial offset of load is perpendicular to the vertical boom plane.

3.2.1.3 Jeep Handling Test. The test was conducted using a military jeep. The jeep handling test was conducted with and without the RBTS. The time required to transfer a jeep between two points (A and B) was recorded. Point A was chosen at approximately 40 feet radius. Point B was chosen 90° away at a radius of approximately 55 feet.

3.2.2 HARBOR TESTS. Harbor tests were conducted at the pier in Little Creek, Virginia. The BE 38-B was installed on timber mats three high in the center of the 4 x 10 NL section. The tests included a functional test, pallet handling test, and container handling test. The pallet and container handling tests were conducted with and without the rider block tagline system attached.

3.2.2.1 Functional Test. This test will be the same as the test described in Section 3.2.1.1.

3.2.2.2 Pallet Handling Test. The test included the transfer of pallets in order from a LASH barge to a LCM 8, placing each pallet on its respectively numbered location. The pallets were then transferred back to the LASH barge. The pallet handling test procedure is as follows:

Arrange the LASH barge and LCM 8 with eight numbered locations in each unit. Begin the operational sequence with the 8 one ton pallets in the LASH barge. Position the hook above the first pallet. Transfer the pallets in order from LASH barge to LCM 8, placing each pallet on its respective numbered location. Record times as per data recording procedures.

Perform the same operations in reverse beginning with pallet #1 and transferring them back to the LASH barge.

Conduct pallet handling exercise with and without the rider block tagline system attached.

3.2.2.3 Container Handling Test. The test included the placement of a spreader bar on a container and the transfer of the container to and from the lighterage. The container handling test procedure is as follows:

Begin with the crane boom axis aligned fore and aft with respect to the causeway, with the spreader bar attached. Swing crane and place the spreader bar on the container. Repeat this operation several times.

Transfer container from the LASH barge to the LCM 8. Repeat spreader placement exercises with container in LCM 8.

Return container to the LASH barge.

Repeat entire series with RBTS.

3.2.3 SEA TESTS. The causeway, with the crawler crane, was positioned in an unsheltered area where the above series of tests were repeated in an operational environment.

SECTION IV
RESULTS

4.1 GENERAL.

This section presents the results of the land, harbor and sea tests. An evaluation of the numerical data is presented, and it is followed by a discussion of the Essential Elements of Analysis (EEA) and Checklist Questions (CLQ) that were presented in the test plan.

4.2 EVALUATION OF NUMERICAL DATA.

The statistical analysis procedure and the results of each test are presented below. Detailed test data sheets are presented in Appendix C.

4.2.1 STATISTICAL ANALYSIS PROCEDURE. In each of a number of the tests conducted, a series of times were recorded for similar operations such as jeep handling, spreader bar placement, and palletized cargo handling. The times were recorded with and without the use of the rider block tagline system. It would be desirable to take this fairly "noisy" data and make some decision about the statistical significance of any comparisons that can be made.

Given two sets of data, X and Y, of N_x and N_y observations, respectively, with means,

$$M_x = \sum_{i=1}^{N_x} \frac{X_i}{N_x} \text{ , and}$$

$$M_y = \sum_{i=1}^{N_y} \frac{Y_i}{N_y} \text{ ,}$$

it is useful to test the null hypothesis that the two samples are drawn from populations with the same mean.

To do this, a new random variable Z is generated such that

$$Z = M_x - M_y.$$

An unbiased estimate of the standard deviation of the population X is

$$\sigma_x = \sqrt{\sum_{i=1}^{N_x} \frac{(X_i - M_x)^2}{N_x - 1}} \quad .$$

If σ_x is the standard deviation of the observations from population X, then the standard deviation of the average of N_x observations from X is

$$\sigma_{M_x} = \frac{\sigma_x}{\sqrt{N_x}} \quad .$$

Similar relations hold for the population Y.

Since the random variable Z is the difference between two other random variables, M_x and M_y, it has a standard deviation of

$$\sigma_z = \sqrt{\frac{\sigma_x^{\ 2}}{N_x} + \frac{\sigma_y^{\ 2}}{N_y}} \quad ,$$

assuming that the samples resulting in M_x and M_y are stochasticly independent.

If the absolute value of Z is greater than twice σ_z, then the null hypothesis will be rejected. That is, there is sufficient statistical information present in the data to indicate a significant difference in the means of the two samples.

A graph of the "power of the test" is shown in Figure 4-1. It shows the probability that the above test will reject the null hypothesis given that the actual difference in the means are various multiples of the standard deviation, σ_z. For example, if the means are the same, the probability of rejection is only .05. If the difference is as little as one standard deviation, the probability of rejection is approximately .12, while if the actual difference is as much as 3 σ_z, the probability of rejecting the null hypothesis has increased to almost .95.

Therefore, it can be seen that if enough observations are taken so that σ_z will be relatively small, then small differences in the means can be detected and interpreted as statistically significant with a reasonable degree of confidence.

The computer program, STAT, Figure 4-2, has been developed to perform the necessary computations on two sets of data, and provides the means, differences, and standard deviations required to test the null hypothesis above.

4.2.2 TEST RESULTS.

4.2.2.1 Land Tests.

4.2.2.1.1 Jeep Handling Tests. The jeep handling portion of the land tests were conducted on 27 June 1977. A point A was located at a radius of 36 feet. Point B was located at a slew angle of 90° from A and at a radius of 50 feet. The jeep was moved four times from A to B and back again with and without the RBTS, resulting in two sets of 8 data points each. These times resulted in a mean of 39.5 seconds for RBTS operation and 39.625 for standard crane

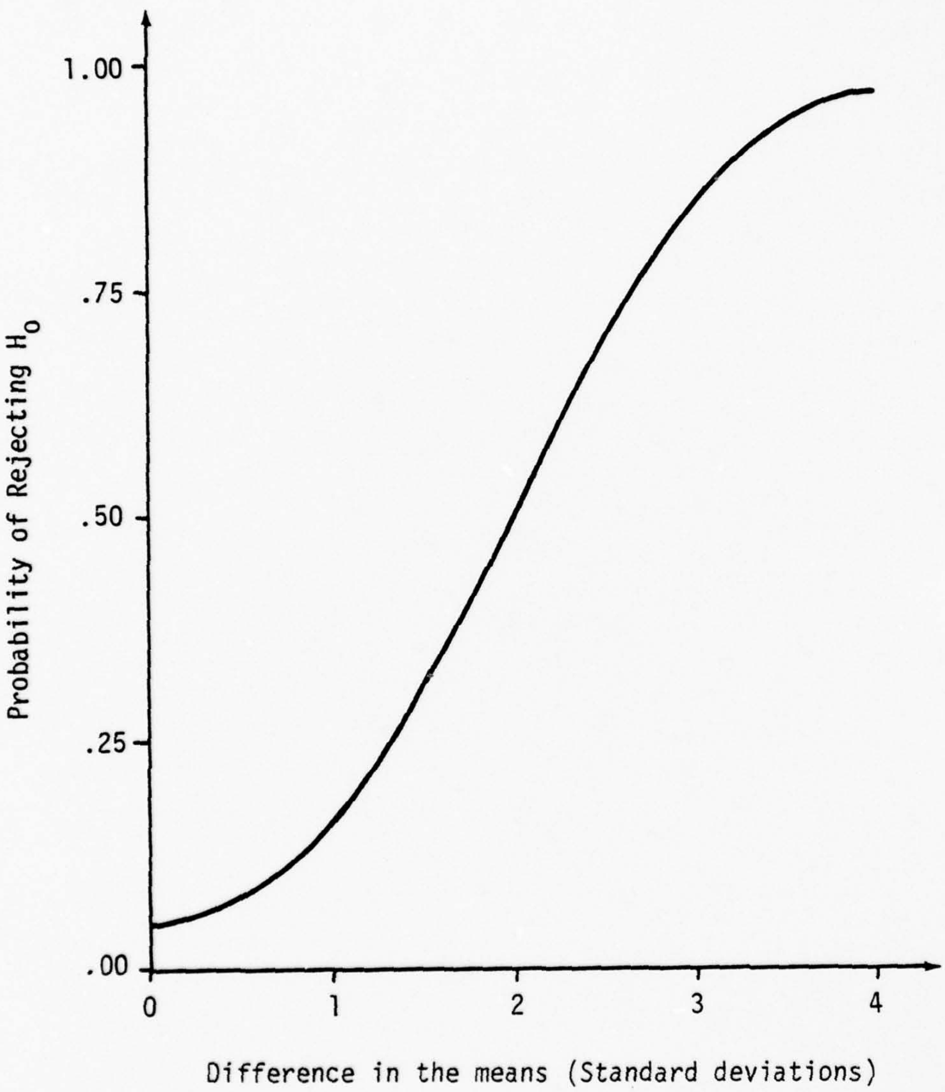


Figure 4-1. Power of the Test

```
LIST

STAT      14:05     11/15/77

1   DATA 8
2   DATA 77,100,116,68,67,64,74,64
3   DATA 8
4   DATA 88,63,84,89,102,76,72,60
100 DIM 9(20),V(5),M(5),N(5)
110 K=0
120 K=K+1
130 READ N(K)
140 X=0
150 FOR I=1 TO N(K)
160 READ S(I)
170 X=X+S(I)
180 NEXT I
190 M(K) = X/N(K)
200 X=0
210 FOR I=1 TO N(K)
220 X=X + (S(I)-M(K))*(S(I)-M(K))
230 NEXT I
240 V(K) = X/(N(K)-1)
250 IF (K=1) THEN 120
260 V(3) = V(1)/N(1) + V(2)/N(2)
270 M(3) = ABS(M(2)-M(1))
280 V(4) - SQR(V(3))
290 PRINT
300 PRINT "","","MEAN","STANDARD DEVIATION"
310 PRINT
320 V(1)=SQR(V(1))
330 V(2)=SQR(V(2))
340 PRINT " ","SAMPLE 1:",M(1),V(1)
350 PRINT " ","SAMPLE 2:",M(2),V(2)
360 PRINT " ","DIFFERENCE",M(3),V(4)
380 END
READY



RUN

STAT      14:06     11/13/77

                                 MEAN          STANDARD DEVIATION

                 SAMPLE 1:       78.75         19.0994
                 SAMPLE 2:       79.25         14.19
                 DIFFERENCE      .5            8.41236
```

Figure 4-2. Computer Program

operation. This indicated that there was no significant difference between the productivity of operations with or without the RBTS when employed in a static, land based application.

4.2.2.1.2 Pendulation Tests. The pendulation tests were conducted at Little Creek on 28 June 1977, in order to simulate the effects of load pendulation when the rider block was substantially below the horizontal of the tagline crossbeam. Some difficulty was experienced in locating the crane in a position over the edge of the pier that would permit as large a negative tagline angle as described in the test plan.

During the off-lead pendulation test, a tagline depression angle of 7.14° was obtained and an initial offset of approximately 12° below the rider block was obtained. When the load was released with a pelican hook, the tagline tensions varied within a 900 pound range and the rider block line varied within a 400 pound range, with a minimum value of 100 pounds. There was no indication that the rider block had any tendency to jump, although theoretically, at sufficiently low rider block positions, the rider block line could become slack. Out-of-plane pendualtion tests were also conducted. The lateral pendulation resulted in the oscillation shifting of tension from one tagline to the other, although neither dropped to a load below 300 pounds. As expected, this component of pendulation had no effect on the rider block line tension.

4.2.2.2 Harbor Tests.

4.2.2.2.1 Container Handling Test. The primary emphasis of the container handling test was the spreader bar placement portion, in which a standard container spreader bar was placed on a container in the LASH barge, out of sight of the crane operator. Each of the three operators made two placement runs from a point on the deck of the causeway.

When this was done with the RBTS, a mean placement time of 131.2 seconds resulted. The same operational sequence was conducted without the aid of the RBTS with a mean placement time of 74.7 seconds. This large discrepancy motivated a rerun of the RBTS portion which resulted in a mean placement time of 61.3 seconds. It was evident that no strong conclusion could be drawn from this data except that the cargo handling team was still ascending the learning curve.

4.2.2.2.2 Pallet Handling Tests. The pallet handling tests were conducted on 17 October 1977 at pierside at the Naval Amphibious Base, Little Creek. Eight dummy pallets of cargo (2000 pounds each) were transferred to and from a LASH barge and an LCM-8. In order to evaluate the statistical significance of the data obtained, the total cycle time was broken down into eight subcycles of "hook over load" to "load touches down". These can now be averaged and compared using the statistical analysis procedure outlined in Section 4.2.1.

During the test, the time was recorded continuously from "hook over load #1" until "load #8 touched down". If unusual circumstances occurred (load lines twisted, pallet slings hung up, etc) that significantly prolonged a portion of a cycle, the data sheet was asterisked at that point. These cycles were omitted from the statistical analysis. For example, during the last cycle of the first run without the rider block, the cranes load lines twisted and became fouled, resulting in a cycle time of 230 seconds where the previous cycles had been averaging about 70 seconds.

The results of the statistical analysis are as follows:

a. From LASH to LCM 8

Mean time w/o RBTS	69.43 sec
Mean time with RBTS	80.00 sec
Difference	10.57 sec
Two Standard Devidations	16.16 sec

NO STATISTICAL DIFFERENCE

b. From LCM 8 to LASH

Mean time w/o RBTS	78.75 sec
Mean time with RBTS	79.25 sec
Difference	0.50 sec
Two Standard Deviations	16.82 sec

NO STATISTICAL DIFFERENCE

4.2.2.3 Sea Tests. The sea tests were conducted on 19 October 1977 off Normandy Beach at Little Creek, Virginia. The objective was to operate in a sea state that would result in significant relative motions between the causeway, the LASH barge, and the LCM 8, but would not prevent cargo handling operations altogether. A desirable significant wave height would have been in the neighborhood of two feet, although substantially less was experienced during the days for which the sea tests were scheduled and conducted.

4.2.2.3.1 Container Handling Test. As in the harbor tests, the primary emphasis of the container handling tests was the spreader bar placement exercises. Although the RBTS on the 38-B was not specifically designed for the purpose, it was used to transfer an empty 20 foot MILVAN container between the LASH barge and an LCM 8 as a heuristic exercise to demonstrate the capability of the RBTS to handle and position large bulky cargo.

A summary of the spreader bar placement exercises conducted at sea follows:

Mean time with RBTS	101.33 sec
Mean time w/o RBTS	96.67 sec
Difference	4.67 sec
Two Standard Deviations	35.40 sec

NO STATISTICAL DIFFERENCE

4.2.2.3.2 Pallet Handling Test. The pallet handling tests were conducted at sea in essentially the same way they were conducted for the harbor tests described in Section 4.2.2.2.2.

The results of the statistical analysis are as follows:

a. From LASH to LCM 8

Mean time w/o RBTS	79.13 sec
Mean time with RBTS	89.86 sec
Difference	10.73 sec
Two Standard Deviations	12.28 sec

NO STATISTICAL DIFFERENCE

b. From LCM 8 to LASH

Mean time w/o RBTS	94.88 sec
Mean time with RBTS	95.57 sec
Difference	0.69 sec
Two Standard Deviations	35.86 sec

NO STATISTICAL DIFFERENCE

The results indicate, that under the conditions of these tests which were:

a. limited capability of the basic crane controls,

b. minimal training of the cargo handling crew in the use of the RBTS ,

c. insignificant relative motions, and

d. limited number of trial runs,

that there was no indication of significant difference in the cargo handling cycles with or without the RBTS.

4.3 DISCUSSION OF THE ESSENTIAL ELEMENTS OF ANALYSIS (EEA) AND CHECKLIST QUESTIONS (CLQ).

Six EEAs will be discussed. The responses to the checklist questions were discussed at the debriefing held on 20 October 1977 at the Amphibious Construction Battalion TWO, Little Creek, Va.

4.3.1 EEA (1) What are the requirements for placing the crane aboard a causeway in terms of material and man hours?

4.3.1.1 CLQ (1.1). Describe the additional reinforcing that is required to support the crane on the deck of the causeway.

No additional reinforcing is required. Conventional causeway modules have adequate strength to support the 50 ton crane on it's standard crawlers.

4.3.1.2 CLQ (1.2). Describe the overall procedure for mounting the crane on the causeway.

After the causeway is beached, the crane is driven onto the causeway (Figure 4-3). The crane is then tied down.

4.3.1.3 CLQ (1.3). Describe the facilities, equipment, and time required to place the crane on the causeway.

Equipment and facilities required are:

a. adequate beach
b. causeway
c. timber matting to assure that there is no metal-to-metal contact, and
d. tie-down chains.

It takes approximately 30 minutes to place the crane on the causeway. An additional one hour is required to tie down the crane and ready it for operation.

Figure 4-3. Driving the Crane on the Causeway

4.3.1.4 CLQ (1.4) Describe the method and equipment used to secure the crane to the deck of the causeway.

Four chains, threaded through pipes placed over the crawler tracks, were secured to the deck of the causeway with load binders. Two cable binders were crossed on either side (Figure 4-4).

4.3.2 EEA (2) Determine the crane's capability to move LASH barge hatchcovers.

4.3.2.1 CLQ (2.1). Describe the hookup requirements (material and personnel).

In order to move LASH barge hatchcovers, a 14 foot sling is required instead of the usual 30 foot sling. Figure 4-5 shows the difference in the length of the slings. The shorter slings greatly increase the effective operational envelope of the RBTS.

The personnel requirements are as follows:

1. Signalman
2. Cargo Handlers

4.3.2.2 CLQ (2.2). Describe the problems associated with removing the hatchcovers.

No significant problems were encountered in removing the hatchcovers.

4.3.2.3 CLQ (2.3). Describe the problems associated with replacing the hatchcovers.

Replacing the hatchcovers was like threading a needle. There was about two feet maximum relative displacement; therefore, critical alignment was required because there were no guides.

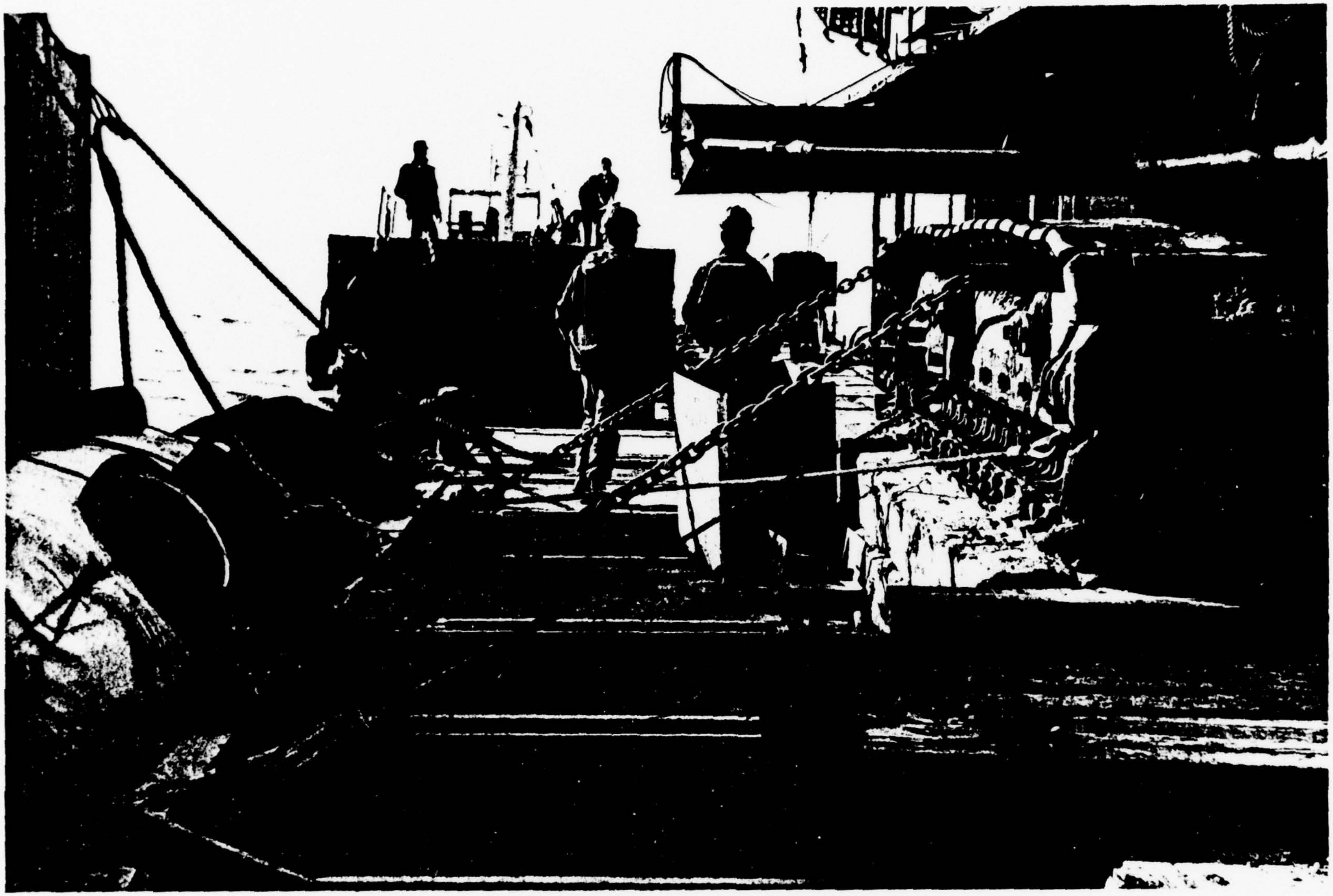


Figure 4-4. Crane Secured to the Deck of the Causeway

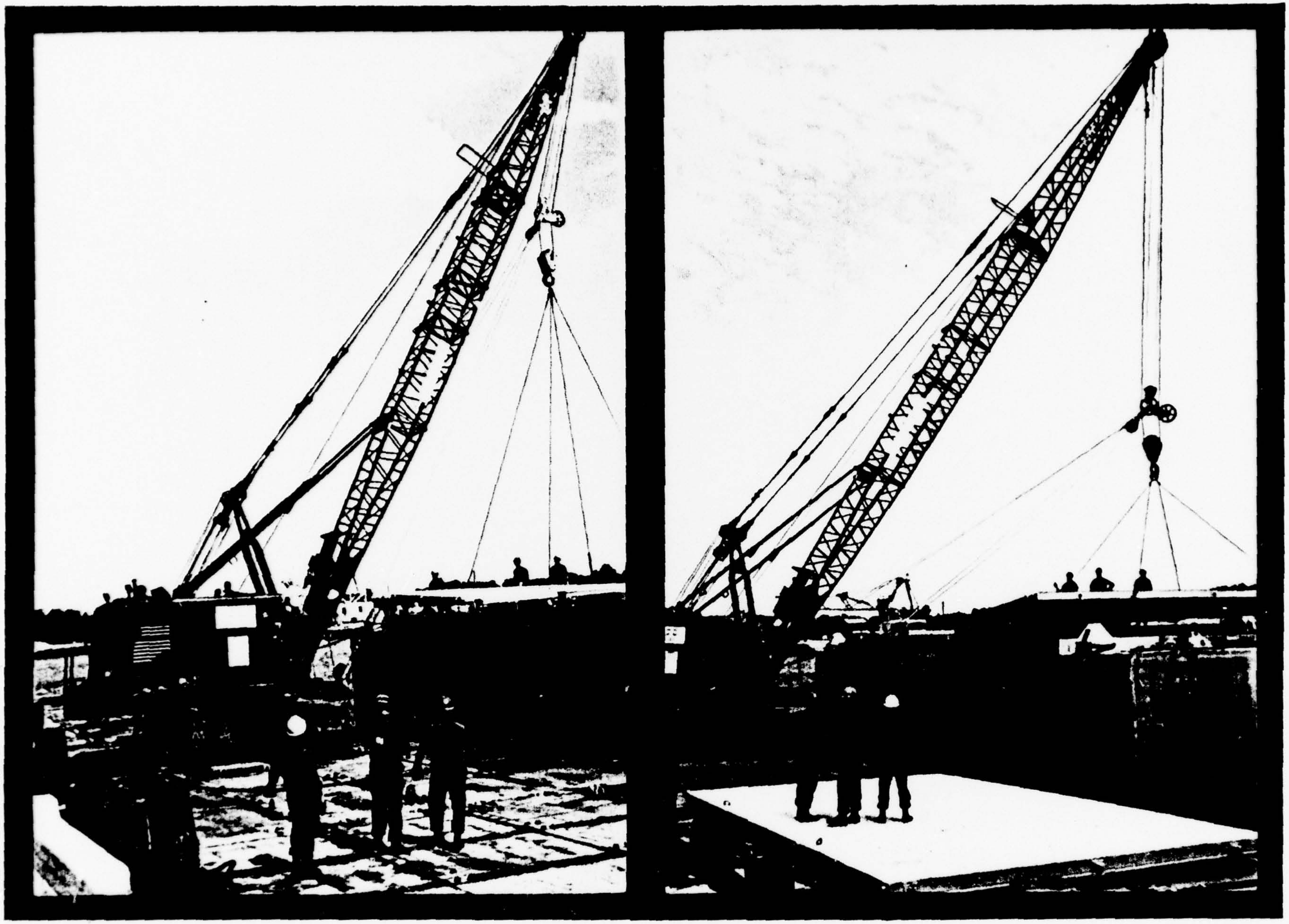


Figure 4-5. Shorter Slings Improve Hatchcover Handling with RBTS

4.3.2.4 CLQ (2.4). Does the RBTS facilitate hatch cover handling operations?

Because of close tolerances, the replacement of hatchcovers is an operation that requires precise alignment between parts of the hatchcover and the barge. The use of the RBTS provided more control of the hatchcover and fine positioning capability. This was particularly evident after repeated attempts to replace the hatchcover with the RBTS over a 20 minute period. When the RBTS was employed, the hatchcover was properly placed on the first attempt.

4.3.3 EEA (3). Determine the crane's ability to transfer palletized cargo between LASH barge and LCM 8 and vice versa.

4.3.3.1 CLQ (3.1) Describe the problems with hooking up to cargo, with and without the RBTS.

There was no particular difference, with and without the RBTS, in hooking up to cargo.

4.3.3.2 CLQ (3.2). Describe the problems with lifting and swinging operations, with and without the RBTS.

When the load block and the rider block were in close proximity, the majority of the load pendulation was eliminated. Additional pendulation was introduced in this test because the swing drive of the crane was rough in one direction. The operator had a tendancy to watch the relative positions of the rider block and the load block to prevent them from "two blocking". This took his attention away from the signalman. It is proposed that a means to safely allow for "two blocking" or an automatic rider block line hoist system be incorporated into the RBTS concept.

4.3.3.3 CLQ (3.3). Describe the problems with positioning cargo in the LCM or LASH, with and without the RBTS.

With and without the RBTS, improved operator visibility of the work area made placing cargo in the LCM 8 a smoother operation than placing cargo in LASH. The signalman on the LCM 8 indicated that with the RBTS he could more accurately position the pallet in the craft.

4.3.3.4 CLQ (3.4). Would pallet handling operations be enhanced by a longer or shorter boom?

A longer boom would have been more effective with this particular rider block because it would increase the effective operational envelope of the rider block.

4.3.4 EEA (4) Determine the crane's ability to transfer containers between the LASH barge and LCM 8 and vice versa.

4.3.4.1 CLQ (4.1). Describe the problem with hooking up to a container in the LASH barge.

The crane operator could not see the operations in the LASH barge, which made positioning a problem with and without the RBTS.

4.3.4.2 CLQ (4.2). Describe the problems with lifting the container clear of the LASH barge.

The crane operator had to lift the container carefully because of the LASH barge dimensions. The full operational envelope was required to lift the container and spreader combination clear of the LASH barge.

4.3.4.3 CLQ (4.3). Describe the problems with swinging the container, with and without the RBTS.

No significant problems were noted. The container was swung in a very controlled manner with the rider block. This evolution was not performed without the rider block.

4.3.4.4 CLO (4.4). Describe the problems with positioning the container in the LCM, with and without the RBTS.

There were no significant problems with positioning the container in the LCM using the RBTS. This evolution was not conducted without the RBTS.

4.3.4.5 CLQ (4.5). Would container handling operations be enhanced by a longer or shorter boom?

A longer boom would have been more effective with the rider block because it would increase the effective operational envelope of the rider block.

4.3.5 EEA (5) What are the real and potential safety hazards involved in this test?

4.3.5.1 CLQ (5.1). List all actual and/or potential safety hazards noted during all operations.

No safety hazards were observed that resulted from the RBTS concept; however, the tagline payout control (described in Section 2.4) was somewhat jerky and introduced some radial pendulation. During preliminary excercises in the rain, the crane hoist brakes became wet and stuck, preventing loads from being lowered slowly. A ladder was needed for the cargo handlers to get in and out of the empty LASH barge. The very short pallet slings required that the load block be lowered to head level during hookup, which may have been dangereous had significant pendulation been observed.

4.3.5.2 CLQ (5.2). How effective was the RBTS in reducing the hazards of pendulation?

The RBTS reduced the lateral pendulation during load positioning.

4.3.6 EEA (6). What are the human factors aspects of the RBTS in an operational environment?

4.3.6.1 CLQ (6.1). Describe the change in the complexity of crane operations because of the additional RBTS controls.

The complexity of the crane operation is increased by the addition of the RBTS controls. After the implementation of the hydraulic tagline brake release, there were a total of three new control levers added to the crane (tagline winch, tagline release, and rider block line) doubling the number used for standard crane operations (load hoist, boom and swing). Additionally, because all five motions are directly driven by the output of the torque convertor and because the relative responsiveness of the controls are not the same and vary somewhat throughout the operational envelope, engine speed must be continually adjusted to maintain optimal control sensitivity. For example, luffing the boom is best performed with a wide open throttle, while tagline operations near the boom require a relatively slow engine speed.

4.3.6.2 CLQ (6.2). Compare the level of stress under which the operator and/or signalmen work with and without the RBTS.

The additional complexity of the crane controls contributes to the level of stress under which the operator must work. Further complexity is introduced by the signalman/operator communication system. Basic crane signals can be given with three easily distinguishable signals for the hoist, boom and swing. The taglines and the rider block line require additional signals that are easy to give and distinguish. It was decided to adopt well known ANSI signals and modify their meaning slightly to fit the requirements of the RBTS. The signal for telescoping hydraulic boom extension and retraction was chosen for the tagline, and the signal for auxiliary hoist was applied to the rider block line. Figures 4-6 and 4-7 present the ANSI Standard Hand Signals.

Probably the largest contribution to the level of stress of the signalmen and operators involved was the increased number of decisions that have to be made while using the RBTS. This point merits further analysis. Consider a conventional crane operation with a requirement to move a load from point A to point B in three dimensional space. The standard crane has three degrees of freedom (hoist, boom, swing), and therefore, there is only one combination of motions that will complete the move. The decisions to be made are reduced to the order in which these motions will be performed. Given the same operation with the RBTS, a mechanical system with five degrees of freedom, there are

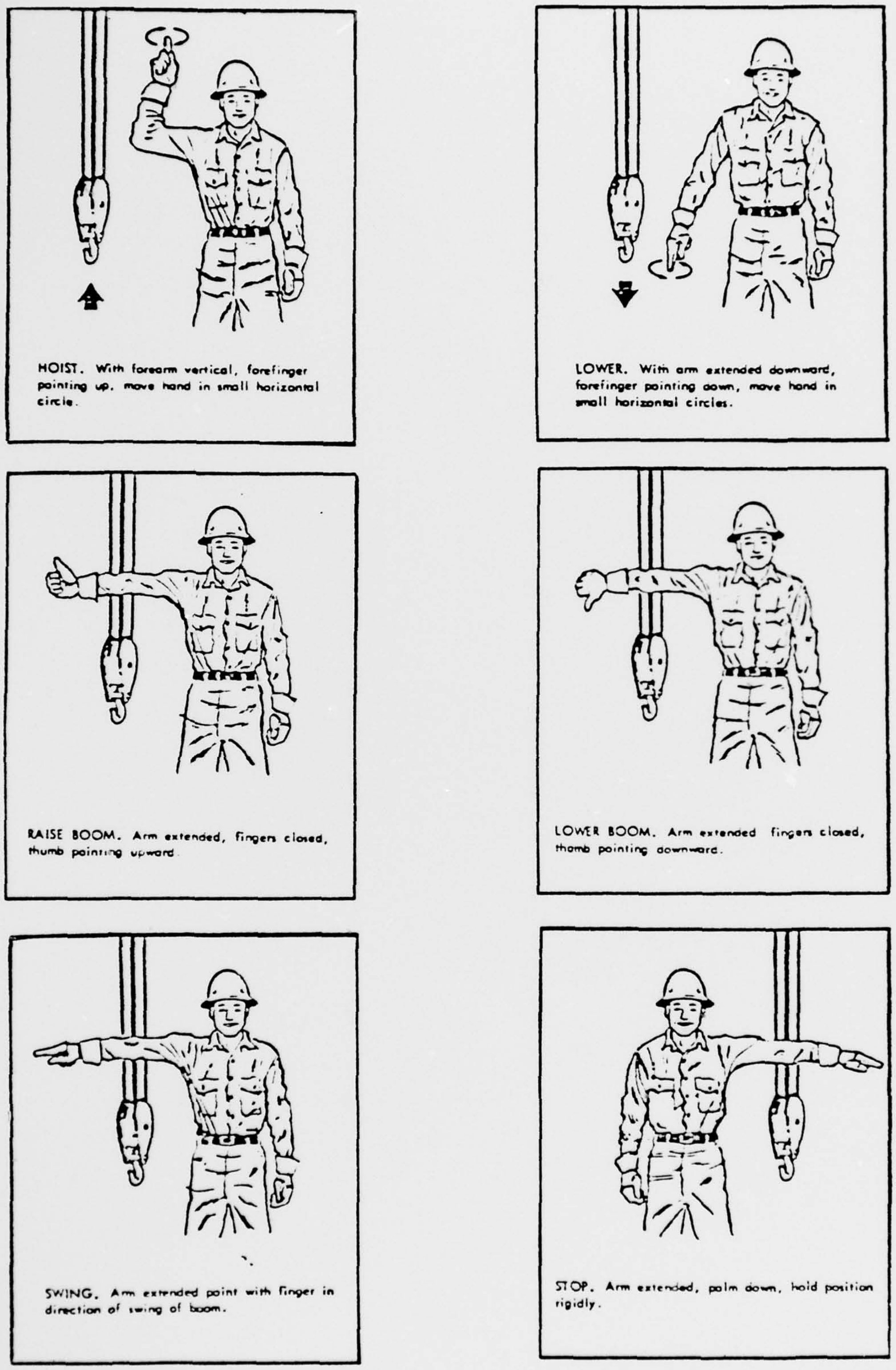
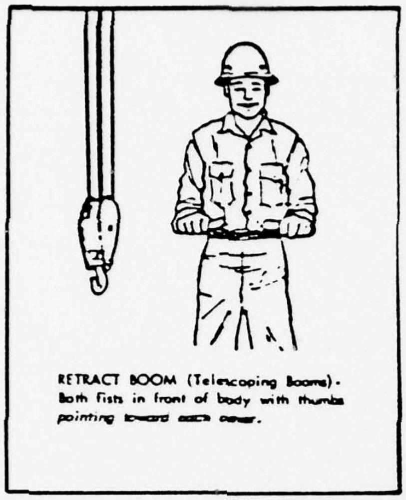
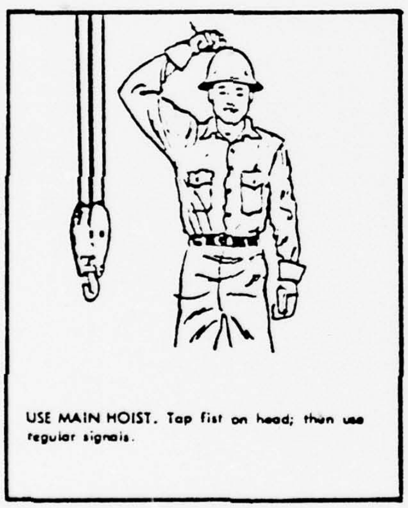


Figure 4-6. ANSI Standard Hand Signals Used for Conventional Crane Operations

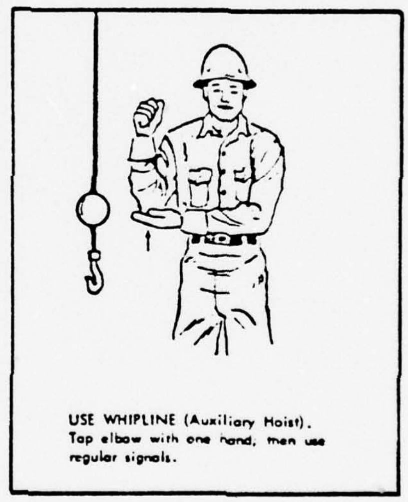


"HAUL IN TAGLINES"

"PAY OUT TAGLINES"



"LOAD LINE"



"RIDER BLOCK LINE"

Figure 4-7. Additional ANSI Standard Hand Signals Adapted for Use with the RBTS theoretically an infinite number of combinations of control sequences that will effect the desired move. This, along with the nonlinear interactions between the RBTS controls, leads to a more difficult and stressful decision making process.

Alternatives, such as redesign of the controls so that the boom luffed automatically in response to extremes of tagline tension, are currently being examined as viable means of facilitating the operation of the RBTS.

An optimistic outcome of the debriefing was the unanimous consensus of the personnel involved that with some classroom training and more field practice (approximately 20 hours per man), the system operation could become almost as natural as driving a car.

4.3.6.2 CLQ (6.3). Describe the level of training required for an experienced crane operator to become proficient with the RBTS.

A military operator has a minimum of seven weeks of training in the basics of crane operation. On the job training continues beyond that. The rider block test was fortunate to have one very experienced military operator, who began working with the crane during the acceptance testing at Ft. Belvoir and continued throughout the tests at Little Creek, and he became fairly proficient with the RBTS. Two other experienced military crane operators, with a brief introduction to the RBTS, also participated in the tests at Little Creek. The general consensus was that approximately 20 hours would be sufficient to familiarize an experienced operator with the RBTS.

SECTION V
CONCLUSIONS

Sea conditions available, within the time frame allocated for the sea tests, were wave heights of less than 1-1/2 feet. The resulting motions were not great enough to require or adequately demonstrate the full capabilities of the RBTS. However, a number of conclusions can be drawn from both the data and the experience resulting from the preparation and execution of the test as a whole. Of particular significance was the fact that the RBTS can be retrofitted to a standard, commercially available, mobile crane.

In spite of the control problems, peculiar to the design of the crane available for this prototype, and the limited indoctrination of the cargo handling crew to the RBTS concept, there was no significant difference in cargo handling productivity. It appears that the performance of the RBTS would be significantly improved when the crane operators and signalmen are given adequate training, and the RBTS controls are effectively integrated into the crane.

Stresses in the boom due to side loading were significantly reduced by the use of the RBTS, as indicated by strain guage data. These stresses have been a major limiting factor in the use of cranes afloat.

Finally, the RBTS proved to be very helpful in the task of replacing the LASH barge hatchcovers at sea. This operation, because of the close tolerances involved in alignment of the mating parts, indicated that the RBTS provided an increased level of load control in a dynamic environment.

SECTION VI
RECOMMENDATIONS

Based on the results of the RBTS DT-IIE test, the following recommendations are made.

1. A full scale RBTS should be built and installed on a COTS capable crane. During the design of this unit, attention should be given to the following features:

   a. Integration of control functions from a human factors standpoint.
   b. Selection of a winch unit that will provide a smooth, controllable actuation of the taglines.
   c. Redesign of the rider block and/or hook block to allow "two blocking" of these units without damage, and the development of an automatic rider block line hoist that will take up the slack in the rider block line when this occurs.
   d. Elevate the attachment points of the tagline outrigger sheaves to increase the operational envelope, if lifts above the level of the crane are to be performed.
   e. Incorporate a rider block position indicator or other means of providing the operator with an indication of load radius.
   f. An audible warning system for excess tension in the taglines.

2. The testing of the full scale RBTS should be conducted under conditions of significant relative motion as described in the COTS operational requirement.

3. A formal training program should be conducted for the operators and signalmen in how to make most effective use of the features and advantages inherent in the RBTS.

APPENDIX A

ACCEPTANCE TEST DATA SHEETS

RUN	BOOM ANGLE	TILT	CHORD STRESS (psi)				LACING STRESS (psi)				LINE TENSION IN POUNDS					LOAD (lbs.)	RIDER BLOCK COORDINATES		TEST PERFORMED
			UPPER RIGHT	UPPER LEFT	LOWER RIGHT	LOWER LEFT	RIGHT	LEFT	TOP	BOTTOM	LEFT TAGLINE	RIGHT TAGLINE	RIDER LINE	LOAD LINE	LUFFING LINE		x(ft)	y(ft)	
1	45	0	-4294	-3477	-1655	-2443	1164	1063	2021	1789	1000	1000	1000	6000	25,500	10,000	33.41	10.82	Operational Test
2			-4527	-4346	-2523	-3512	757	600	993	993	2150	2050	2800	5500	21,000		28.00	12.96	Operational Test
3			-4536	-4790	-2923	-4233	725	425	783	757	3400	3125	5100	7000	21,000		25.90	14.25	Operational Test
4			-4510	-3965	-2433	-3027	1260	1120	1568	1699	950	1025	1000	6000	26,000		35.43	14.86	Operational Test
5			-4644	-4253	-2437	-3388	889	521	1443	1376	2050	2000	3000	6000	24,000		30.76	16.41	Operational Test
6			-4568	-4652	-2810	-4117	814	398	1399	1267	3300	2700	5400	7000	22,000		28.49	17.96	Operational Test
7			-4842	-4457	-2323	-3335	799	547	1791	1542	1350	950	1600	6000	27,500		36.32	22.56	Operational Test
8			-4782	-4591	-2436	-3813	981	598	1893	1637	2700	2225	4000	6000	25,500		33.88	23.75	Operational Test
9			-5019	-4959	-2519	-4195	957	354	1829	1475	3400	2975	5500	6500	25,500		32.90	24.24	Operational Test
10	60	0	-3457	-2091	-2718	-3088	-138	-303	-276	-70	900	1000	1400	6000	17,000		21.19	8.94	Operational Test
11			-3319	-3164	-2830	-3420	-262	-488	-476	-273	2000	2000	3300	6200	16,000		16.60	10.38	Operational Test
12			-2682	-3194	-2933	-3699	-8	-306	-342	-110	2975	2975	4700	7100	11,500		14.55	10.89	Operational Test
13			-3117	-3184	-2761	-3240	116	-76	-7	196	900	1000	1400	6000	17,000		24.17	16.34	Operational Test
14			-3055	-3230	-3553	-3371	171	-327	-38	229	1900	2025	3300	5900	15,000		20.60	16.94	Operational Test
15			-3103	-3501	-3005	-3851	236	-127	-79	296	2800	3025	5100	6000	13,500		18.81	17.79	Operational Test
16			-3317	-3756	-3154	-3859	-71	19	-13	5	1100	950	1700	6000	18,000		26.38	24.51	Operational Test
17			-3194	-3891	-2936	-4050	107	-111	270	164	2200	2000	3900	6100	17,000		23.66	25.70	Operational Test
18			-3044	-3989	-2961	-4309	511	186	639	453	3100	2800	5600	6000	16,000		22.55	26.04	Operational Test
19	60	3	-1933	-2610	-1925	-3278	502	-113	527	502	2550	2975	4000	5500	11,000		14.94	11.10	3^{o} List Test
20			-2170	-2250	-1734	-2549	689	264	904	913	150	1125	500	6500	17,000		23.25	8.58	3^{o} List Test
21			-2086	-2571	-2010	-3300	661	-62	736	845	2050	2950	4000	6500	13,000		17.81	15.55	3^{o} List Test
22			-2279	-2491	-1846	-2874	499	35	859	789	150	1200	700	6500	17,500		25.26	14.07	3^{o} List Test
23			-2203	-3282	-2148	-4006	620	-176	855	635	2400	3000	4650	6500	14,500		20.96	20.89	3^{o} List Test
24			-2133	-2899	-1623	-3153	556	84	1143	700	150	950	600	6500	19,500		27.71	19.71	3^{o} List Test
25	45	3	-3528	-4239	-2169	-3826	909	65	1236	999	2200	2975	3500	6000	21,500		26.30	11.41	3^{o} List Test
26	45		-3780	-4247	-2051	-3363	1076	447	1598	1246	150	1150	300	6000	28,500		36.94	7.85	3^{o} List Test

RUN	BOOM ANGLE	TILT	CHORD STRESS (psi)				LACING STRESS (psi)				LINE TENSION IN POUNDS					LOAD (lbs.)	RIDER BLOCK COORDINATES		TEST PERFORMED
			UPPER RIGHT	UPPER LEFT	LOWER RIGHT	LOWER LEFT	RIGHT	LEFT	TOP	BOTTOM	LEFT TAGLINE	RIGHT TAGLINE	RIDER LINE	LOAD LINE	LUFFING LINE		x(ft)	y(ft)	
27	45	3	-3413	-4924	-2161	-4473	1014	92	1540	962	2900	3075	4500	6200	23,000	10,000	29.68	16.49	3^{o} List Test
28			-3491	-4302	-1904	-3386	1261	629	1936	1400	150	1000	400	6200	29,200		39.28	13.07	3^{o} List Test
29			-3257	-4382	-1952	-3886	1521	687	2312	1775	2150	3025	3800	6500	25,500		34.14	21.31	3^{o} List Test
30			-2883	-3943	-801	-2972	1625	970	3164	1893	150	525	200	6100	31,000		41.31	18.96	3^{o} List Test
31		3	-2462	-3863	-200	-2766	1857	1301	3686	2079	Load Hanging Vertical								
32	60	6	-1255	-3725	-1111	-4308	44	151	1083	444	Load Hanging Vertical								
33	60	6	-894	-1844	-1302	-3096	430	9	761	393	2400	3000	4000	7200	12,200		15.25	10.17	6^{o} List Test
34			-1254	-1449	-1125	-2362	527	369	1031	790	150	1400	600	6500	17,500		23.44	7.72	6^{o} List Test
35			-1553	-2184	-1513	-3318	239	370	604	431	1900	3025	3650	7000	14,000		18.90	14.48	6^{o} List Test
36			-1798	-2085	-1587	-3032	-10	-180	472	284	150	1600	1000	6500	18,000		24.55	12.00	6^{o} List Test
37			-2100	-3924	-2250	-4971	-516	-918	-234	-681	2450	3000	4500	6500	16,000				6^{o} List Test
38			-4142	-6034	-5500	-7020	-1511	-932	-2512	-2340	150	1300	800	6500	20,000		28.86	20.82	6^{o} List Test
39	45		-5900	-7792	-5949	-7690	-1087	-900	-2271	-2034	2200	2950	2800	6500	25,000		28.63	11.68	6^{o} List Test
40			-6268	-7598	-5978	-7163	-1082	-644	-2104	-1819	150	1600	400	6000	30,500		35.93	8.56	6^{o} List Test
41			-6263	-7792	-5847	-7316	-991	-671	-1936	-1735	1950	3100	3000	7000	27,000		30.87	15.48	6^{o} List Test
42			-6245	-8382	-6125	-8203	-952	-808	-1835	-1758	150	1575	500	6000	31,000		36.92	13.73	6^{o} List Test
43			-6728	-8155	-5424	-7510	-831	-489	-1399	-1809	2200	3075	3500	6600	28,500		33.90	21.04	6^{o} List Test
44											150	850	300	6000	34,000		40.42	18.28	6^{o} List Test

APPENDIX B

BUCYRUS - ERIE 38-B

STANDARD CRAWLER

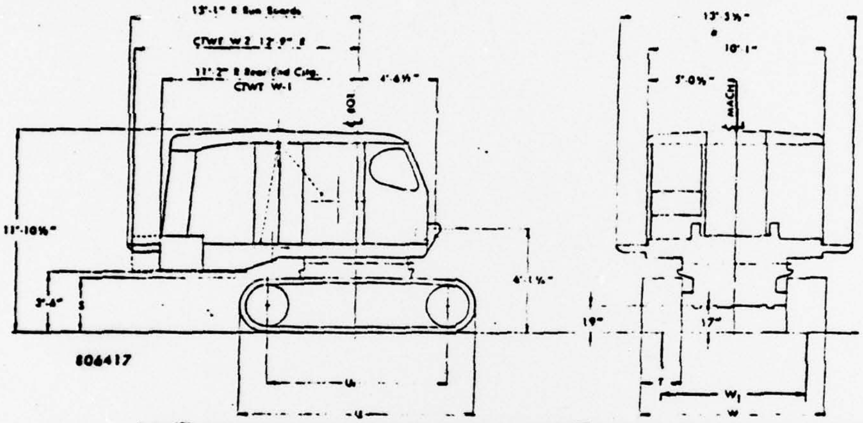
SPECIFICATIONS

BUCYRUS-ERIE

38-B

SERIES TWO

STANDARD CRAWLER SPECIFICATIONS



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Crawler Mountings	Height Tread Belts S	Width Treads T	Length Overall U	C. to C. Tumblers U_1	Overall Width Tread Belts W	Overall Width (Retracted) W_1	Approx. Bearing Area Sq. Ft.
Long Frames 35½ in. treads	3 ft. 3 in.	35½ in.	17 ft. 5 in.	14 ft. 3 in.	11 ft. 11 in.	10 ft. 11 in.	90.0

WEIGHTS IN POUNDS

	Shovel	Hoe	Crane 45 Ft. Boom	Dragline 45 Ft. Boom	Clamshell 45 Ft. Boom
Net Domestic, approx.	117,300	111,500	93,800	94,700	94,250
Working, approx.	118,500	112,700	95,900	99,100	102,400
Export shipping, approx.	119,300	113,500	96,700	99,900	103,200
Ships option tons	80	91	80	85	86

Hook block and buckets included in working weight and export shipping weight, but not in domestic net weight.

LINE PULLS AND SPEEDS

Drum Pitch Diameter (Inches)	1 Part Line		2 Part Line		3 Part Line	
	Pull in Lbs.	Speed F.P.M.	Pull in Lbs.	Speed F.P.M.	Pull in Lbs.	Speed F.P.M.
20	27,300	164	53,700	82	79,400	57
22½	24,200	185	47,500	98	70,600	62
25	22,000	205	43,400	103	63,100	75

Swing Speed 3.5 r.p.m. Propel Speed 0.95 m.p.h.

Speeds and line pulls based on diesel engine, torque converter drive operating at full load speed of the output shaft. When torque converter is operating at full stall, line pulls are approximately 220 per cent of those shown in table.

POWER SPECIFICATIONS

Make	GM	Cummins	Caterpillar
Model	6-71N	NH 250-IP	D-333-CT
Type	Diesel	Diesel	Diesel
Type of Drive	Tor. Conv.	Tor. Conv.	Tor. Conv.
Cylinders	6	6	6
Bore x stroke, inches	4¼ x 5	5½ x 6	4¾ x 6
Displacement, cu. in.	425.6	855	638
Rated for excavator service at full load speed of output shaft:			
Output shaft speed R.P.M.	1315	1315	1315
Output shaft Net H.P.	145	146	146
Fuel tank capacity, gals.	115	115	115
Crankcase capacity, qts.	28	32	24
Cooling system capacity, gals.	11	21	11
Starting	12V-Electric	12V-Electric	12V-Electric
Altitude range, feet	0-4,000	0-6,500	0-10,000

CRANE

Hoist drum, grooved (R.H.)....20 in. P. Dia.
Hoist rope ....⅞ in. Dia.
Aux. hoist drum, gr'ved (L.H.) 22½ in. P. Dia.
Aux. hoist rope ....⅞ in. Dia.
25 in. P. Dia. drums, optional
Boom point sheaves (2) ......20 in. P. Dia.

DRAGLINE

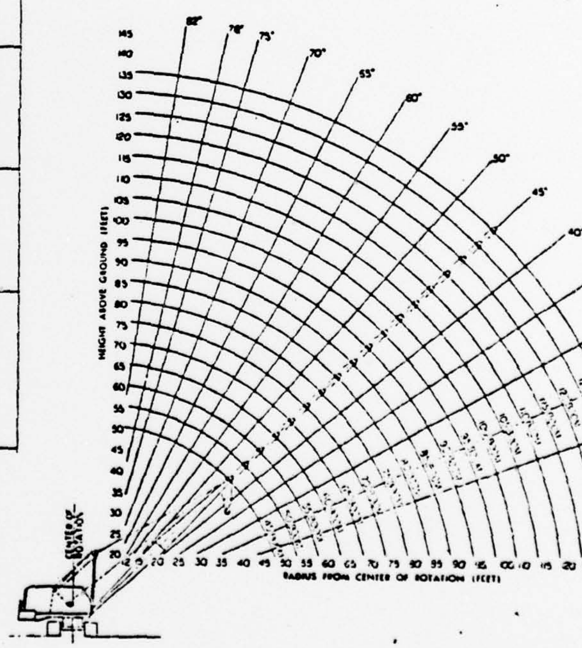
Hoist drum, grooved (L.H.)..22½ in. P. Dia.
Hoist rope, 1-part ....⅞ in. Dia.
Drag drum, grooved (R.H.)..22½ in. P. Dia.
Drag rope, 1-part ....1 in. Dia.
Boom point sheave (1) ....20 in. P. Dia.

38-B CRANE

41 TON CRAWLER CRANE (CLASS 12-154)

MAXIMUM ALLOWABLE LOADS IN POUNDS — CRANE SERVICE						
Boom Length In Feet	Radius In Feet	Boom Angle In Degrees	Boom Point Pin Height (Ft. In.)	Standard Crawler		Long Crawler
				Ctwt. W-1	Ctwt. W-2	Ctwt. W-2
45	12	80	50 6	63.600	77.700	82.300
	15	77	50 0	44.700	54.700	58.000
	20	70	48 6	29.500	36.300	38.600
	25	63	46 3	21.800	26.900	28.600
	30	56	43 3	17.100	21.200	22.600
	35	47	39 3	14.000	17.400	18.500
	40	38	33 9	11.700	14.700	15.600
50	15	78	55 0	44.500	54.500	57.800
	20	72	53 9	29.300	36.100	38.300
	25	66	51 9	21.600	26.700	28.400
	30	59	49 3	16.300	21.000	22.400
	40	45	41 6	11.500	14.500	15.400
60	15	80	65 3	44.200	54.300	57.500
	20	75	64 3	29.100	35.800	38.100
	25	70	62 6	21.300	26.500	28.100
	30	65	60 6	16.300	20.800	22.100
	40	54	54 6	11.200	14.200	15.200
	50	41	45 3	8.250	10.500	11.300
70	15	81	75 6	44.000	54.000	57.300
	20	77	74 6	28.900	35.600	37.800
	25	73	73 3	21.100	26.200	27.900
	30	69	71 6	16.400	20.500	21.900
	40	60	66 6	11.000	14.000	14.900
	50	50	59 6	8.000	10.300	11.000
	60	38	49 0	6.050	7.950	8.550
80	20	79	84 9	28.600	35.400	37.600
	25	75	83 6	20.800	26.000	27.600
	30	71	82 0	16.200	20.300	21.600
	40	64	78 0	10.700	13.700	14.700
	50	55	73 0	7.750	10.000	10.800
	60	46	63 9	5.800	7.700	8.300
	70	35	52 3	4.450	6.050	6.600
90	20	80	96 0	28.300	35.100	37.400
	30	74	92 6	15.900	20.000	21.400
	40	67	89 0	10.500	13.500	14.400
	50	60	84 0	7.500	9.800	10.500
	60	52	77 0	5.550	7.450	8.100
	70	43	68 0	4.250	5.850	6.300
	80	33	55 3	3.250	4.650	5.100
110	20	82	115 0	27.800	34.700	36.900
	30	77	113 3	15.400	19.600	20.900
	40	71	110 3	10.000	13.000	13.900
	50	66	106 6	7.000	9.300	10.100
	60	60	101 3	5.100	6.950	7.600
	70	53	94 6	3.750	5.350	5.850
	80	47	86 3	2.750	4.150	4.600
	90	39	75 6	2.000	3.200	3.600
	100	30	60 9	1.400	2.500	2.950

HOOK BLOCKS				
Capacity	No. Parts	Y		
		78 Deg. (Ft. In.)	82 Deg. (Ft. In.)	Weight (Pounds)
5 Ton	1	4 0	4 0	220
25 Ton	2	7 0	7 0	425
40 Ton	4	12 0	13 0	910
60 Ton	6	12 0	12 0	1.050



HOIST TACKLE

Parts:

Suggested parts of hoist tackle are as follows (loads in pounds):

Loads Over	15.000	30.000	45.000	60.000
Parts of Line	2	3	4	5

The maximum allowable load for a single part line on the auxiliary hoist line is 15.000 pounds.

Hook Blocks:

5 Ton weighted hook for jib weighs .... 220 lbs.
25 Ton swivel, single sheave, hook block weighs.. 425 lbs.
40 Ton swivel, double sheave, hook block weighs.. 910 lbs.
60 Ton swivel, triple sheave, hook block weighs..1050 lbs.

The above ratings apply only to machines that are level and standing on hard level uniform supporting surfaces. **Loads must be** freely suspended. The radii specified are loaded radii. Weights of hook, hook block, sling and all other **load** handling and load indicating devices are to be considered part of the load. Proper care must be exercised by the operator at all times to avoid shock or side loadings on the boom. Ratings apply only to machines having booms in first class condition built and recommended by Bucyrus Erie Company.

Loads do not exceed 75 percent of tipping loads with the machine in the least stable position in accordance with U.S. Department of Commerce Commercial Standards CS 90 58.

APPENDIX C

DETAILED TEST DATA

JEEP HANDLING TEST DATA SHEET

Radius of Point A 36 (ft)

Radius of Point B 50 (ft)

Operation Time (sec)

	With RBTS	Without RBTS
A to B	44	47
B to A	46	40
A to B	41	44
B to A	42	41
A to B	39	38
B to A	35	38
A to B	38	35
B to A	31	34

PENDULATION TEST DATA SHEET

☑ In Plane ☐ Out of Plane

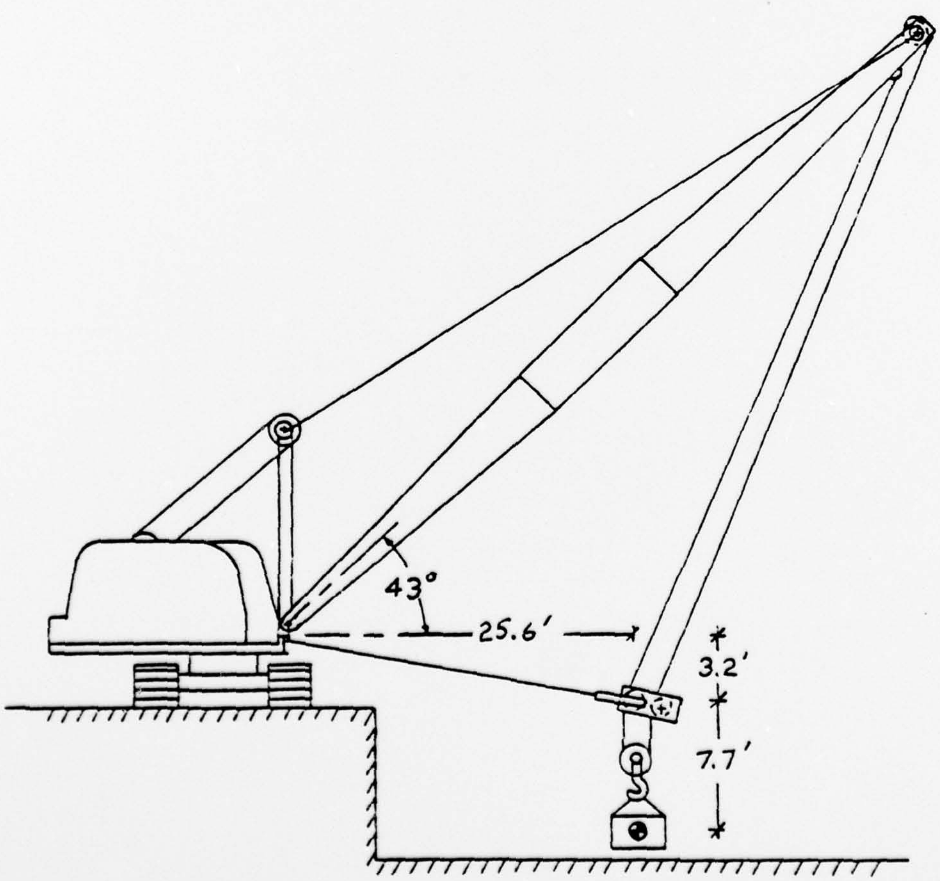
Test Weight 5800 (lbs)

Initial Load Offset Below R.B. 16"

Tension Data (lbs)

	Left Tagline	Rider Block	Right Tagline
Static	500	400	300
Offset	400	300	250
Maximum	1400	500	1200
Minimum	500	100	300

Boom Length = 70′



Static Test Conditions

PENDULATION TEST DATA SHEET

☐ In Plane ☑ Out of Plane

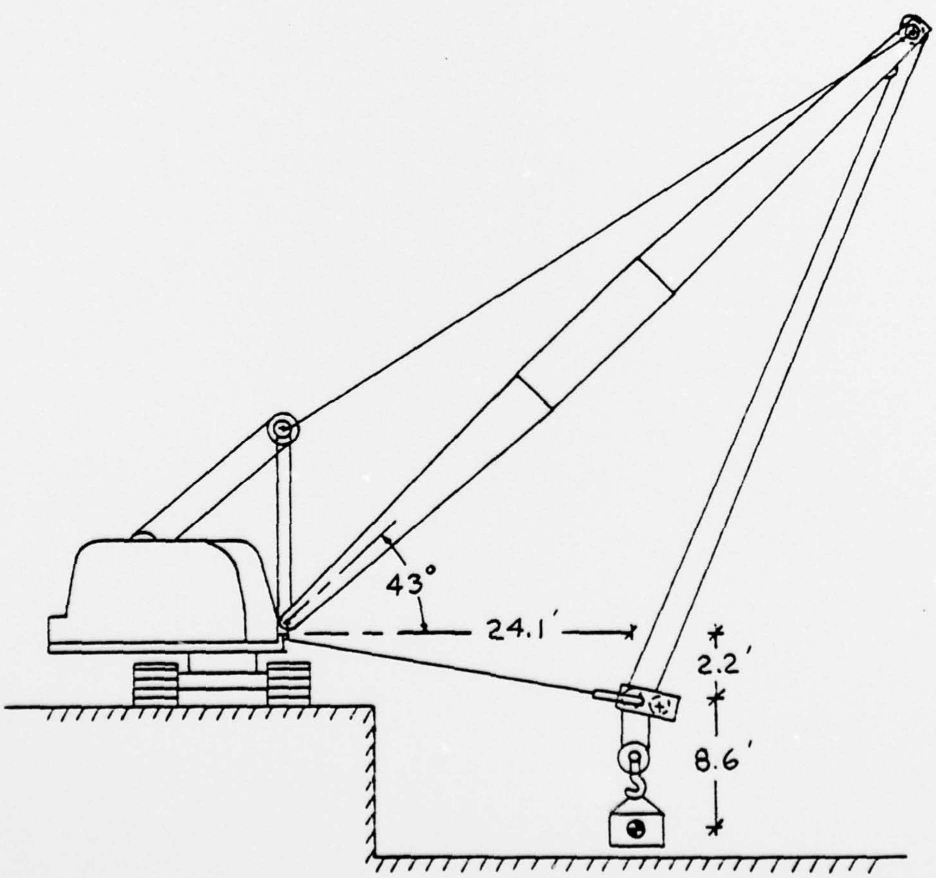
Test Weight 5800 (lbs)

Initial Load Offset Below R.B. 12"

Tension Data (lbs)

	Left Tagline	Rider Block	Right Tagline
Static	1100	300	600
Offset	1250	300	250
Maximum	1200	300	1100
Minimum	600	300	300

Boom Length = 70'



Static Test Conditions

CONTAINER SPREADER BAR PLACEMENT DATA SHEET

HARBOR

Run #1 W/RBTS

Run #2 W/OUT RBTS

Run #3 W/RBTS

Transfer Time (sec)

Trial	Run #1	Run #2	Run #3
1	4:20	1:57	1:04
2	2:15	1:22	1:07
3	1:43	1:20	0:58
4	2:30	:50	1:08
5	1:13	:49	:58
6	1:06	1:10	:53

SEA

Run #1 w/ RBTS

Run #2 w/out RBTS

Run #3

Transfer Time (sec)

Trial	Run #1	Run #2	Run #3
1	2:05	2:00	
2	1:20	1:20	
3	1:45	1:55	
4	1:33	1:40	
5	2:40	1:30	
6	:45	1:15	

PALLET HANDLING TEST PROCEDURES AND DATA SHEETS

☑ Harbor ☐ Sea

Pallet Description 2000 lb. load on std. wood pallets

Run #1 w/out RBTS, Lash → LCM8
Run #2 w/out RBTS, LCM8 → Lash
Run #3 with RBTS, Lash → LCM8
Run #4 with RBTS, LCM8 → Lash

Cycle Times (sec)

Operations	Run #1	Run #2	Run #3	Run #4
hook over load #1	0	0	0	0
load leaves ground	37	15	31	30
begin swing	50	25	55	45
stop swing	1:05	35	1:01	56
load touches down	1:26	1:17	1:23	1:28
return swing begins	1:55	1:50	1:43	1:55
hook over load #2	2:20	2:00	2:07	2:35
load leaves ground	2:50	2:30	2:30	2:52
begin swing	3:20	2:32	2:45	3:01
stop swing	3:27	2:43	2:56	3:17
load touches down	3:35	3:40	3:04	3:38
return swing begins	3:55	4:00	3:30	4:05
hook over load #3	4:25	4:25	3:40	4:24
load leaves ground	4:50	4:55	3:55	4:53
begin swing	5:10	5:10	4:18	4:58
stop swing	5:20	5:25	4:42	5:16
load touches down	5:26	6:21	4:55	5:48
return swing begins	5:45	7:47	5:08	6:18

(Continued)

	Run #1	Run #2	Run #3	Run #4
hook over load #4	6:10	8:12	5:50	6:43
load leaves ground	6:35	8:38	6:10	7:01
begin swing	6:50	8:40	6:20	7:10
stop swing	7:00	8:55	6:38	7:23
load touches down	7:10	9:20	6:41	8:12
return swing begins	7:36	9:53	7:05	8:51
hook over load #5	8:20	10:25	7:55	9:13
load leaves ground	8:45	10:36	8:15	9:49
begin swing	9:05	10:45	9:00	9:56
stop swing	9:20	11:10	9:25	10:16
load touches down	9:32	11:32	9:30	10:55
return swing begins	10:35	12:00	10:01	11:26
hook over load #6	11:05	12:36	10:46	11:47
load leaves ground	11:25	12:45	11:20	12:07
begin swing	11:43	12:55	11:33	12:15
stop swing	12:00	13:15	11:47	12:31
load touches down	12:15	13:40	12:01	13:03
return swing begins	12:53	14:06	12:20	13:40
hook over load #7	13:20	14:32	12:52	14:03
load leaves ground	13:55	14:55	13:14	14:22
begin swing	14:10	15:00	13:32	14:34
stop swing	14:20	15:15	13:48	14:49
load touches down	14:22	15:46	13:56	15:15
return swing begins	14:50	16:30	14:22	15:40
hook over load #8	15:50	16:43	15:08	16:10
load leaves ground	19:27*	17:07	15:33	16:37
begin swing	19:30	17:15	15:47	16:44
stop swing	19:35	17:30	16:03	17:00
load touches down	19:40	17:47	17:10	17:10

PALLET HANDLING TEST PROCEDURES AND DATA SHEETS

☐ Harbor ☑ Sea

Pallet Description 2000 lb. load on std. wood pallets

Run #1 w/out RBTS, Lash → LCM8
Run #2 w/out RBTS, LCM8 → Lash
Run #3 with RBTS, Lash → LCM8
Run #4 with RBTS, LCM8 → Lash

Cycle Times (sec)

Operations	Run #1	Run #2	Run #3	Run #4
hook over load #1	0	0	0	0
load leaves ground	30	15	40	35
begin swing	50	30	1:00	1:05
stop swing	1:05	45	1:15	1:15
load touches down	1:25	1:30	2:00*	2:45*
return swing begins	1:40	2:00	2:30	3:25
hook over load #2	2:00	2:22	4:00	3:31
load leaves ground	2:30	3:35	4:18	4:45
begin swing	2:45	3:45	4:40	5:03
stop swing	3:00	4:00	4:50	5:20
load touches down	3:13	4:25	5:10	6:15
return swing begins	3:32	5:03	5:30	7:05
hook over load #3	3:52	5:25	6:10	7:20
load leaves ground	4:30	6:15	6:55	7:55
begin swing	4:52	6:25	7:20	8:10
stop swing	5:08	6:40	7:35	8:30
load touches down	5:17	7:25	7:50	8:40
return swing begins	5:32	7:57	8:10	9:10

(Continued)

	Run #1	Run #2	Run #3	Run #4
hook over load #4	5:55	8:25	8:55	9:40
load leaves ground	6:32	8:53	9:25	10:05
begin swing	6:48	9:00	9:50	10:17
stop swing	7:05	9:12	10:05	10:35
load touches down	7:15	9:27	10:20	11:15
return swing begins	8:05	10:15	10:40	12:00
hook over load #5	8:30	10:40	11:15	12:25
load leaves ground	9:00	11:05	11:40	13:45
begin swing	9:20	11:13	11:55	13:58
stop swing	9:35	11:25	12:15	14:00
load touches down	9:45	11:50	12:30	15:45
return swing begins	10:20	12:10	12:45	16:00
hook over load #6	10:37	12:50	13:05	16:40
load leaves ground	11:10	13:12	13:20	17:05
begin swing	11:25	13:27	13:50	17:12
stop swing	11:40	13:48	14:12	17:35
load touches down	11:47	14:40	14:47	17:53
return swing begins	12:10	15:10	15:20	18:32
hook over load #7	12:30	15:35	15:30	19:00
load leaves ground	13:10	16:22	16:10	19:30
begin swing	13:25	16:30	16:35	19:35
stop swing	13:42	16:50	17:00	19:57
load touches down	13:50	17:40	17:10	20:05
return swing begins	14:20	18:17	17:22	20:40
hook over load #8	15:00	19:00	17:55	21:00
load leaves ground	15:35	19:30	18:30	21:20
begin swing	15:57	19:35	18:37	21:35
stop swing	16:10	19:47	18:55	21:45
load touches down	16:25	20:10	19:20	21:52