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NAVY CRANE CENTER
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK NAVAL SHIPYARD, BUILDING 491
PORTSMOUTH, VIRGINIA 23709-5000.

IN REPLY REFER TO

NAVCRANECENINST 11450.2
18 March 2013

NAVCRANECEN INSTRUCTION 11450.2

From: Director, Navy Crane Center

Subj: DESIGN OF NAVY SHORE WEIGHT HANDLING EQUIPMENT

Ref: (a) SECNAVINST 11260.2A, Navy Weight Handling Program
for Shore Activities

(b) NAVCRANECENINST 11450.1A, Acquisition of Navy
Shore Based Weight Handling Equipment

(c) NAVFAC P-307, Management of Weight Handling
Equipment

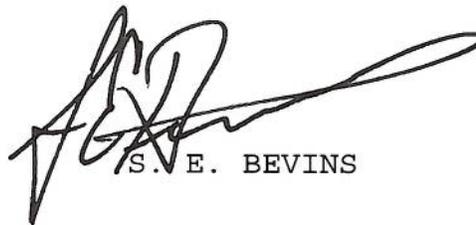
Encl: (1) Design of Navy Shore Weight Handling Equipment,
18 March 2013

1. Purpose. To revise the requirements of Unified Facilities Criteria (UFC) 3-320-07N and provide the latest design standards for new and altered Navy shore weight handling equipment (WHE), and present these criteria in a new format and document.
2. Cancellation. Unified Facilities Criteria (UFC) 3-320-07N. Navy Crane Center plans to transition NAVCRANECENINST 11450.2 to a tri-service UFC in the future after a joint tri-service effort coordinated with the Air Force and Army is completed.
3. Background. Reference (a) assigns responsibility for the direction and oversight of all matters pertaining to the Navy's weight handling program at Navy shore activities to the Commander, Naval Facilities Engineering Command. Reference (a) further states that these responsibilities shall be accomplished through the Navy Crane Center directly reporting to the Commander, Naval Facilities Engineering Command. Included among these responsibilities are development and maintenance of policy regarding design criteria and acquisition of WHE.

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4. Policy. Navy Crane Center's WHE design policy is contained in enclosure (1) of this instruction. This design policy shall be used as the basis for technical specifications for the procurement of new and overhauled shore based WHE. This design policy shall also be utilized as the technical basis for crane alterations. See reference (b) for policy on acquisition of Navy shore based WHE. The processes for crane alterations are provided in reference (c).

5. Applicability: This instruction is applicable to WHE at Navy shore activities and detachments and shore-based fleet activities and detachments. For questions on this Instruction, please contact Navy Crane Center Director of Engineering at DSN 387-3802 COMM 757-967-3802.



S. E. BEVINS

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DESIGN OF NAVY SHORE WEIGHT HANDLING EQUIPMENT

NAVCRANECENINST 11450.2

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Record of Changes:

Change No.	Date	Synopsis of Change from UFC 3-0320-07N
Original Issue	3/18/2013	<ol style="list-style-type: none">1. Wholesale revision incorporating changes in crane design and utilization that have occurred since the original revision of UFC3-320-07N issued in January 2004 and change 1 issued in May 2007 and Change 2 in August 2007.2. Extensive renumbering and format change; this instruction no longer resembles the format of the previous UFC or Mil-Handbooks.3. Consolidation of Special Purpose Service (SPS) crane design requirements from various NAVFAC and NAVSEA manuals into this instruction.4. Update of technical specifications in all areas to match latest crane designs.5. Revision of electrical specifications to incorporate latest variable frequency design requirements.6. Clarified requirements for hoist brakes.7. Clarified package hoist rules, allowing some components not previously permitted.8. Addition of procurement specifications for rigging equipment.

This NAVCRANECENINST supersedes UFC 3 -320-07N dated 15 May 2007.

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CHAPTER 1 INTRODUCTION

1-1 **BACKGROUND.** This document is derived from material originally contained in Department of the Navy Bureau of Yards and Docks Technical Publication, NAVDOCKS TP-Tr-24, Weight Handling Equipment, of 15 October 1955. TP-Tr-24 was published as a technical guide for civilian and military personnel concerned with selection, design, procurement, fabrication, erection and acceptance testing of weight-handling equipment. NAVFAC Design Manual, DM-38.1, Weight Handling Equipment, was published in June, 1982, incorporating the content of TP-Tr-24 along with MIL-C-22137, Cranes, Overhead Traveling, Overrunning Bridge and Trolley, Electric Powered. DM 38.1 was in turn superseded by MIL-HDBK-1038, Weight Handling Equipment, in March 1998. Unified Facilities Criteria (UFC) 3-320-07N, Weight Handling Equipment, superseded MIL-HDBK-1038 in January 2004, and was revised in 2007. The original purpose of TP-Tr-24 is retained in this instruction for selection, design, procurement, fabrication and modification of weight handling equipment.

1-2 **PURPOSE.** This instruction provides descriptions of the predominant crane types in service at Navy shore facilities. It outlines general design requirements for new weight handling equipment and the pertinent engineering methodology for evaluation of older and contemporary crane and rigging equipment design.

Numerous exceptions to the crane configurations, design features, and design criteria of this instruction can be found in the Navy crane inventory – all with a record of successful performance. Unless the safety or performance of these exceptions becomes questionable they should be left intact.

This instruction should not be used solely as a reference document for the procurement of cranes. It should be used for the development of technical specifications for the design, construction, and installation of cranes, and other weight handling equipment.

1-3 **SCOPE.** This instruction cites and supplements existing Government and commercial standards and specifications for the design and fabrication of weight handling equipment and applies to Navy shore activities and shore-based fleet activities and detachments.

1-3.1 **Applicability to Existing Cranes.** The design requirements of this instruction are intended to apply to cranes according to the revision in effect on the date that the crane is placed in service. Existing cranes (including both “older cranes” and “newer cranes” as described below) that do not comply with the design criteria presented in the latest revision of this instruction (or preceding documents), may remain in service if they have a history of satisfactory performance. When assemblies or components of existing cranes need to be repaired or replaced, they should be upgraded to the criteria of the latest revision of this instruction where it is practical to do so. Navy Crane Center controls this upgrading process for U.S. Navy shore assets through the review and approval of Crane Alteration Requests (CARs), as mandated in NAVFAC P-307.

1-3.2 **Standard Commercial Items and Components.** The applicability to and usage of this instruction to off-the-shelf items is specified below. However, compliance with the requirements will vary among commercial items and crane vendors. It is the end user's responsibility to procure items that comply with this instruction, to the maximum extent practicable, and document non-compliances together with the reason why non-compliance does not affect safety, reliability, or NAVFAC P-307 certifiability.

1-3.2.1 **Applicability to and Usage of Standard Commercial Components.** To be used on cranes, standard commercial components shall comply with applicable recognized industry design standards and meet the design factors required in this instruction when used on custom designed and built-up hoists and cranes and when specifically required (e.g., hooks on mobile boat hoists).

1-3.3 **Applicability to Mobile Cranes, Articulating Cranes, Pedestal Cranes, and Mobile Boat Hoists.** The applicability of this instruction to design features, materials, and other requirements apply to mobile cranes, articulating cranes, pedestal mounted hydraulically telescoping and/or luffing boom cranes (non B30.4 type), and mobile boat hoists only when explicitly stated.

1-3.4 **Key Definitions.** The terms "older cranes", "newer cranes", "standard commercial", "package hoist", "custom design(ed)", "built-up", "shall" and "should" are used throughout this handbook. Their definitions follow.

- a) *Older cranes*, in the case of portal and floating cranes, are those designed and built prior to the early 1980's; *newer cranes* are those of the later period. Their prominent visual distinctions are illustrated in Appendix B. Container cranes and the vast majority of mobile cranes still in service are all in the newer crane category. The distinction among the other crane types is less identifiable, but the most visible features on older cranes are riveted structural connections, extensive use of open gearing, wide use of castings, and imprecise material identification.
- b) *Standard commercial* or commercial assemblies and components are those items readily available off-the-shelf from manufacturers specializing in the design and production of such items. This definition encompasses package hoists and hoist/trolley units, speed reducers, brakes, spreaders, hooks, wheels, etc. For the purposes of this instruction, "standard commercial" and "off the shelf" have the same meaning.
- c) *Package hoists* are commercially designed and mass produced hoists characterized by the motor, gearing, brake(s) and drum contained in a single package often connected by the use of c, d, or p-face flanges. This is in contrast to a "built-up" or "custom designed" hoist.

- d) *Custom designed* and *built-up* are terms applied to items of original or unique design, including entire cranes, assemblies, and components. A custom designed or built-up hoist typically utilizes separate motors, gearboxes, brakes, and a drum, each component usually having its own foundation, and usually connected by couplings.
- e) *Shall*, as used in this instruction, the term “shall” indicates a required feature, component, item, or characteristic.
- f) *Should*, as used in this instruction, the term “should” indicates a recommended feature, component, item, or characteristic, and one that is normally provided on a crane procured by the Navy Crane Center.

1-3.5 **General Building Requirements.** Navy facilities shall comply with UFC 1-200-01, *Design: General Building Requirements*. If any conflict occurs between this instruction and UFC 1-200-01, the requirements of UFC 1-200-01 take precedence.

1-3.5.1 **Safety.** Navy projects shall comply with OPNAVINST 5100.23 (series), *Navy Occupational Safety and Health Program Manual*. The most recent publication in this series can be accessed at the NAVFAC Safety web site: www.navfac.navy.mil/safety/pub.htm. If any conflict occurs between this instruction and OPNAVINST 5100.23, the requirements of OPNAVINST 5100.23 take precedence.

1-3.5.2 **Fire Protection.** Navy facilities shall comply with UFC 3-600-01, *Design: Fire Protection Engineering for Facilities*. If any conflict occurs between this instruction and UFC 3-600-01, the requirements of UFC 3-600-01 take precedence.

1-3.6 **Related Criteria.** This instruction covers many varieties of cranes, and consequently references many design standards and criteria specifications. In order to make the relationship of such standards and specifications to the crane types clear and unambiguous, they are listed under Industry Standards paragraphs of the particular crane type description to which they apply. UFCs and UFGS's related to this instruction include:

- UFC 3-301-01 Structural Engineering
- UFC 3-310-04 Design: Seismic Design for Buildings
- UFC 3-460-01 Design: Petroleum Fuel Facilities
- UFC 3-501-01 Electrical Engineering
- UFC 3-540-04N Diesel Electric Generating Plants
- UFC 4-152-01 Design: Piers and Wharves
- UFC 4-152-07 Design: Small Craft Berthing Facilities
- UFC 4-159-01N Design: Hyperbaric Facilities
- UFC 4-159-02 Engineering and Design of Military Ports
- UFC 4-171-01N Design: Aviation Training Facilities
- UFC 4-211-01N Aircraft Maintenance Hangars: Type I, Type II, Type III
- UFC 4-212-01N Navy Engine Test Cells

UFC 4-213-10 Design: Graving Docks
UFC 4-213-12 Drydocking Facilities Characteristics
UFC 4-440-01A Storage Depots
UFC 4-442-01N Design: Covered Storage
UFGS 41 22 13.33 Portal Crane Track Installation

1-3.7 **Unified Facilities Guide Specifications.** Unified Facilities Guide Specifications (UFGS) that implement the requirements of this instruction for commonly procured crane and hoist configurations include:

UFGS 41 22 13.13, Bridge Cranes (20,000 to 60,000 pounds capacity);
UFGS 41 22 13.14, Bridge Cranes, Overhead Electric, Top Running (less than 20,000 pounds rated capacity);
UFGS 41 22 13.15, Bridge Cranes, Overhead Electric, Under Running (less than 20,000 pounds rated capacity);
UFGS 41 22 13.16, Gantry Cranes (20,000 to 60,000 pounds rated capacity); and,
UFGS 41 22 23.19, Monorail Hoists.

Navy shore crane procurement policy prohibits the acquisition of any crane with a rated capacity of 10 tons or greater, or for other than general purpose service without Navy Crane Center approval. Navy shore crane acquisition shall follow the requirements of Navy Crane Center Instruction 11450.1 (latest revision).

1-3.8 **Innovations.** The crane industry continuously develops advances in the control systems and features, improved arrangements and design of components, and new materials. Introduction of cost-effective technically-sound design innovations, whether proposed by the crane contractors or Government activities, is encouraged. Innovations on existing Navy cranes shall be implemented via the Crane Alteration Request (CAR) process; and on new Navy crane procurements they may be introduced during the development of the contract specifications or by change order after contract award.

1-3.9 **Foreign Design Standards and Practices.** Foreign design standards and engineering practices are acceptable, provided they are accompanied by satisfactory explanation and are shown to meet corresponding U.S. standards and practices.

1-3.9.1 **Translation and Engineering Units.** Design calculations and drawings that use foreign language and nomenclature shall include corresponding English equivalents. Metric units may be used for both calculations and shop drawings, but they shall include conversions to English units. In the case of calculations, only the initial inputs and final results need to be so converted.

1-3.9.2 **Professional Credentials.** Professional training and accreditation of foreign engineers may vary in some aspects from those in the U.S., but they are satisfactory if comparable for the design work in which they engage.

1-3.9.3 **Materials.** Mechanical properties and quality standards of common construction materials of foreign sources supplied in accordance with recognized standards that resemble those of ASTM and other U.S. standards are acceptable.

1-3.9.4 **Welding.** Typically, foreign welding procedures, materials, standards, and welder qualifications are comparable to those of AWS and are therefore acceptable. All necessary certifications and other data shall be provided for review and approval prior to start of work. Special attention shall be given to ensure the weld sizes are being specified and measured uniformly.

1-3.9.5 **Wire Ropes.** Unique constructions and metric sizes not complying with Federal Specification RR-W-410, the Wire Rope Users Manual, or ASTM A1023/A, may be used on Navy cranes, subject to Navy Crane Center review and approval of the specific applications.

In selecting metric wire ropes for installation on new cranes the metric diameter shall be within the limits of the wire ropes for which the sheave is grooved. When the wire rope is to be installed on an older crane with sheave and hoist drum grooves configured for a specific U.S. produced wire rope type, the sheave and hoist drum grooving shall be considered to ensure a satisfactory match with the wire rope.

1-3.9.6 **Components.** The capacities or ratings of components produced in foreign countries in compliance with foreign standards, and their installation requirements, shall be converted to the English engineering units and verified for specification compliance.

1-3.9.7 **Special Consideration on Foreign Products.** Some components from foreign sources are prohibited due to practical considerations – either susceptibility to counterfeiting or maintenance and timely support. Specific examples are:

1-3.9.7.1 **High-Strength Structural Bolts and Nuts.** The use of structural bolts from foreign manufacturers is allowed provided the bolts meet AISC/RCSC Specification for Structural Joints Using High-Strength Bolts.

1-3.9.7.2 **Electrical Controls.** Electronic controls of foreign manufacturers are prohibited unless documented technical support is available in the U.S.

1-3.10 **Crane Information Forms.** An appropriate crane information form shall be completed by the supported command prior to the preparation of the crane procurement specification. Crane Information Forms for the most frequently procured crane types can be found in various industry standards and under Downloads on the Navy Crane Center web site, <http://portal.navfac.navy.mil/ncc>.

Crane information forms document and communicate all operating characteristics and requirements as well as limiting dimensions, clearances, access platforms, and interferences with load hooks in their operating envelope that affect crane design. For design of new buildings, typical crane dimensions and required clearances may be obtained from the Whiting Crane Handbook. Since under running

cranes are primarily standard commercial products, manufacturers' catalogs should be reviewed to ascertain various configurations, dimensions, and the required clearances.

Similar forms and sketches shall be prepared by the supported command for other crane types, using sample forms as a guide for the appropriate information and level of detail, to procure a crane design suitable for the operational requirements and fully adapted to the site conditions.

1-3.11 **Facility Interfaces.** Design of buildings and new facilities shall account for installation and operation of supporting cranes. Considerations include clearances from obstructions, crane wheel loading, crane repair and replacement, and stringent tolerances for crane rail alignment. Consult crane construction references, crane facility design guides, and Navy Crane Center for specific design guidance.

For portal and container cranes, it is desirable to have the crane delivered nearly fully assembled. Consequently, the off-loading location on the waterfront shall be identified and fully described. Alternatively, if extensive assembly/erection at the site is envisioned, that area shall be clearly marked in sketches prepared and submitted as part of the crane information forms. Additionally, clearance envelopes of the entire crane shall be outlined. The curves in the rail system layout shall be accurately defined in order to establish the required travel truck float.

1-3.12 **Request for Clarification, Deviation, or Revision.** Requests for clarification, deviation, or revision to this instruction shall be documented using a "Request for Clarification, Deviation, or Revision," (RCDR) figure 1-1 of NAVFAC P-307. Appropriate references, enclosures, background, and reason for request shall be provided. RCDRs posted on Navy Crane Center's web site are applicable to all activities.

CHAPTER 2 TECHNICAL GUIDANCE

2-1 **STRUCTURAL.** Structural design of some cranes and particular components and assemblies follows the general design criteria of the American Institute of Steel Construction (AISC) and specific requirements of the Navy Crane Center. Specifications of the Crane Manufacturers Association of America (CMAA), the Monorail Manufacturers of America (MMA) and the American Society of Mechanical Engineers (ASME) provide comprehensive design methodology and criteria for top running and under running single and multiple girder electric bridge, gantry, and monorail cranes. The paragraphs that follow outline the minimum structural design requirements for each crane type. Deviations from these criteria for Navy cranes are prohibited, unless approved by Navy Crane Center.

2-1.1 **Structural Design Loads.** The following is a brief discussion of loads that are usually considered in the design of many types of cranes.

2-1.1.1 **Dead Load.** Dead load consists of the weight of all parts of the structure, machinery, and equipment, including the load blocks and rope.

- (a) A portion of the dead load on cranes, such as trolleys and booms, shall be considered as moving dead load.
- (b) On portal and floating cranes, a large portion of the dead load is moving dead load. On these types of cranes, the center of gravity of the boom, strut, load blocks, and rope shall be accounted for at each hook radius considered in design.

2-1.1.2 **Rated Load.** The maximum rated capacity of the hoist is considered as a vertical static load on the hook.

This load produces reactions throughout the crane structure that also shall be considered in the design of individual components – for example, wire rope loads on sheaves and drums.

2-1.1.3 **Impact.** Impact is the term commonly used for the vertical dynamic forces of the lifted load due to handling.

- (a) Percentages of increase, or impact factors, for bridge, gantry, monorail, and cantilever cranes are given in the applicable industry standards (CMAA #70, CMAA #74, MMA MH27.1). CMAA specifications use the term “inertia” instead of “impact” and the phrase “hoist load factor”.
- (b) For portal and floating cranes, the impact factors shall not be less than the minimum values given in Table 2-1.

- (c) Percentages of increase for other types of cranes may be determined by a rational method of analysis, or by the manufacturer's standard practice.

Table 2-1 Percentages of Increase for Impact for Portal and Floating Cranes

Rated Hook Capacity (Pounds)*	Portal Cranes			Floating Cranes	
	Upper works	Portal Base/Tower	Travel System**	Upper works	Tub
Under 100,000	30	15	25	15	10
100,000 to 160,000	25	12	25	15	10
161,000 to 240,000	20	10	25	15	10
Over 240,000	15	10	25	15	10

* Use the maximum rating for variable rated cranes.
** Impact on travel system is applied to the total vertical load.

2-1.1.4 **Wind Load.** The magnitude of the wind load is to be determined by a procedure contained in a generally recognized engineering standard or code, such as ASCE/SEI 7, which accounts for maximum gust velocity (for non-operating wind load), and additional considerations such as shape and height. Operating wind does not restrict operation. Non-operating wind prohibits crane operation.

- (a) Cranes operating in outdoor environments shall be designed with the consideration of loads due to wind, both for operating and non-operating wind conditions.
- (b) Wind loads for top running bridge, gantry, and semi-gantry cranes are addressed in CMAA #70; and for under running cranes, in CMAA #74. ASME B30.2 and B30.17 require every outdoor crane to be provided with secure fastenings convenient to apply and hold the crane against a wind pressure of 30 pounds per square foot (psf) or against the maximum wind load for the location per ASCE/SEI 7 if in excess of 30 psf.
- (c) Operating wind loads for other crane types shall be calculated based on the maximum local operating wind velocity. Non-operating wind loads for other crane types shall be calculated based on the wind gust velocity at the geographic location in accordance with ASCE/SEI 7. Standard practice is to use 40 miles per hour (mph) for the operating wind case (55 mph for container cranes).

2-1.1.4.1 **Wind Gust Velocity.** Newer cranes are designed for maximum wind gust velocity at the geographic location; however, the configurations of the cranes vary as follows:

- (a) Portal cranes shall meet stability requirements for the non-operating wind velocity in the cranes least stable configuration.
- (b) Provisions shall be made for putting the crane into a stable stowed configuration for maximum wind gust conditions. This may include setting the boom at a greater radius, using a more stable rotate position, stowage pins, rail clamps, chocks, and providing slide protection or tie-downs, if required.
- (c) In its stowed configuration, the crane shall meet the strength and stability requirements for its maximum non-operating wind velocity.
- (d) The wind speed above which the crane shall be placed in its stowed position shall be clearly indicated in drawings and the operator's cab.

2-1.1.5 Acceleration and Deceleration Forces.

- (a) The acceleration and deceleration of the travel drives and rotate drives (if applicable) produce horizontal loads that shall be considered in design.
- (b) For portal cranes, floating cranes, and cantilever cranes, the rate of acceleration is based on accelerating from a standstill to the rated speed of the drive in 8 seconds.
- (c) The rate of deceleration, caused by loss of power or emergency stop, is considered to be an extraordinary load.
- (d) Rates of acceleration for top running cranes and under running cranes are given in the applicable industry standards (CMAA #70, CMAA #74, and MMA MH27.1). For cranes with user programmable acceleration/deceleration parameters, the highest rates of acceleration/deceleration allowed by the crane manufacturer shall be used in design.

2-1.1.6 Spreading and Squeezing Forces. The portal base of a portal crane is subjected to spreading and squeezing forces when traveling in curves. The friction forces due to these forces, are applied to all travel wheels horizontally (and perpendicular to the rail axis) at the contact points on the rails. The spreading and squeezing forces are taken as 12 percent of the maximum wheel load caused by dead load and rated load. Designing a portal base for lateral loads of this magnitude (concurrently with other operating loads) has been found to give it sufficient lateral strength at the corners.

2-1.1.7 **Seismic Forces.**

- (a) Seismic building loads are transmitted to the crane through the building structure.
- (b) Overhead cranes in buildings (top running cranes, under running cranes, and monorails) are classified as mechanical components (a specific type of non-structural component) by ASCE/SEI 7 for seismic design.
- (c) The effects of seismic forces on the trolley/hoist units of monorails are considered to be negligible for under running trolley hoists where the trolley hoist is free to swing on the monorail beam. Similarly, the effects of seismic forces on some parts of under running cranes may also be considered to be negligible depending on the type of trolley mounting, runway suspension, and end trucks used.

2-1.1.7.1 Seismic Analysis for Overhead Cranes. The need for seismic analysis is determined using the Seismic Design Category and the importance factor I_p of the facility. The Seismic Design Category and I_p are defined in ASCE/SEI 7. I_p is equal to 1.0 for most cranes in normal service.

- (a) For cranes with I_p equal to 1.0, seismic analysis is required only for facilities with a Seismic Design Category of D, E, or F.
- (b) Design consideration may be required for retention of the load and prevention of any component from becoming a missile in a seismic event.

As an alternative, ASME NOG-1 may be used for seismic analysis.

2-1.1.7.2 Seismic Forces on Under Running Cranes and Monorails. The effects of seismic forces on the trolley/hoist units of monorails are considered to be negligible since the trolley is free to swing on the runway beam. Similarly, the effects of seismic forces on some parts of under running cranes may also be considered to be negligible depending on the type of trolley mounting, runway suspension, and end trucks used. If not considered negligible, seismic analysis shall be determined as required in paragraph 2-1.1.7.1.

2-1.1.7.3 Seismic Forces on Other Crane Types. Container cranes, portal cranes, free-standing bridge cranes, and gantry cranes may need to be analyzed for seismic forces, depending on their location and their use. The crane structure shall be treated as a non-building structure with an ordinary moment-resisting steel frame, and analyzed by the methodology of the International Building Code (IBC) and ASCE/SEI 7.

2-1.1.8 **Additional Loads on Floating Cranes.** A horizontal sideload is applied to floating cranes. This load is a combination of the accelerating forces due to rotate motion, and the sidelead forces due to maximum list and trim.

- (a) Floating cranes are required to be towed at sea, and shall be designed for the wave motion that they will experience.
- (b) The resulting roll, pitch, and heave are determined by the selected sea state; and their dynamic effects are calculated by a rational method of analysis, which shall be approved by the Navy Crane Center.
- (c) Tie downs and locking provisions are normally required for the boom and upper works to resist these forces.
- (d) Tie downs may be required for elevated operator's cabs and similar structures.
- (e) Additional vertical support for the counterweight may also be required.
- (f) A-frames of floating cranes are usually designed with additional bracing to resist these forces.

2-1.2 **Structural Connections.** (Applicability includes commercial components)

2-1.2.1 **Welding Design.** Welding design and weld details are governed as follows:

Table 2-2 Welding Design Table

Crane Type	Specification Number	Specification Name
Top Running	AWS D14.1	<i>Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment</i>
Under Running	AWS D14.1	<i>Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment</i>
Cantilever	AWS D1.1	<i>Structural Welding Code – Steel</i>
Portal	AWS D1.1	<i>Structural Welding Code – Steel</i>
Floating	ABS	<i>Rules for Building and Classing of Steel Barges</i>
Container	AWS D1.1	<i>Structural Welding Code – Steel</i>
Mobile	AWS D14.3	<i>Specification for Earthmoving and Construction Equipment</i>
Gantry and Semi-Gantry	AWS D14.1	<i>Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment</i>

2-1.2.2 **Bolted Structural Connections.** Bolted connections and bolt installation shall comply with the AISC/RCSC Specification for Structural Joints Using High-Strength Bolts.

2-1.2.3 **Structural Pins.**

- (a) Structural pins should be solid forgings; hollow pins (heavy wall tubes) may be used only with Navy Crane Center approval.
- (b) Pinned joints shall be designed to put the pin into double shear. These pinned joints do not require provisions for lubrication .
- (c) The engaging end of the keeper bar for a circumferential groove should be coped to fit the groove diameter.
- (d) Circumferential grooves are required due to the tendency of some pins to creep rotationally and break the keeper bars or fasteners.
- (e) If only one end is retained with the keeper bar, then the pin length should be sufficient to allow the straight section (excluding the chamfer) of the free end to protrude beyond the face of the structure by at least 1/8 of the bore diameter.
- (f) Large pins may have a tapped hole on one or both ends for temporary installation of an eye-bolt for handling and extraction of the pin. Pins are normally installed with anti-seize or other initial lubrication.
- (g) Welded bars on the end of pins, intended to function as both head and keeper bar, are prohibited because of the tendency of the weld to crack

2-1.3 **Design of Top Running Bridge Cranes. (Applicability includes commercial components)**

- (a) These cranes shall be designed in accordance with CMAA #70 and the additional requirements of this standard.
- (b) Unique requirements (such as test load cases), special features (such as field splices of bridge girders), and other items which are beyond the scope of CMAA #70 shall be addressed separately by the Navy Crane Center in the procurement specifications.
- (c) The alignment of the top running runway system shall comply with CMAA #70 requirements to ensure proper traveling of the bridge. If this is not possible, the crane specification shall clearly state this existing condition.

2-1.3.1 **Structural Components.**

2-1.3.1.1 **Bridge Girders.**

- (a) For cranes in CMAA #70, Class C, D, or E service, box girders are recommended for spans greater than 40 feet and for cranes with rated capacities of 20 tons or more (especially when walkways are supported from the girders). Unless otherwise specified Class C is the lightest duty specified for Navy service.
- (b) Single web bridge girders may be built-up (welded) or standard rolled structural shapes.
- (c) Single web bridge girders are particularly susceptible to lateral torsional buckling, and shall always be analyzed conservatively for this condition with the appropriate lateral and torsional load applied. Vertical or transverse stiffeners may be required on the sides of the web and the flanges.
- (d) The ends of the bridge girders, both box section and single web type, should be notched (stepped) to fit over the end truck.
- (e) The girders shall be reinforced at the notches with vertical diaphragms and horizontal stiffeners.
- (f) The bottom flanges should be tapered towards the notches.
- (g) The bridge rails should be centered over the top flange and secured with rail clips or clamps. If rail joints cannot be avoided due to the length of the span, the joints shall be staggered and located directly over girder diaphragms. Optionally, the rails may be positioned directly over one of the box girder webs, in which case the short diaphragms may be omitted, but the girder box section shall be designed for the additional torsional loads due to this eccentric loading. The gaps at rail joints shall be less than 1/32 of an inch.
- (h) Bar stock shall not be used for bridge rail.
- (i) The rail clips or clamps may be welded directly to the top flange or fastened with nuts and threaded studs welded to the top flange. The clips or clamps shall not be spaced more than 36 inches apart. Hook bolts may only be used for light duty cranes with Navy Crane Center approval.
- (j) The rails should be free to shift longitudinally but the amount of movement shall be limited.

2-1.3.1.2 **Walkways (Footwalks).**

- (a) New cranes equipped with footwalks should have a full-length footwalk on each girder and a crossover footwalk across an end tie or trolley. The exact footwalk requirement will be determined by the user activity depending upon hook envelope needs.
- (b) On cab equipped cranes, the crossover footwalk should be on the cab end of the girders.

2-1.3.1.3 **End Trucks and End Ties (for Eight-Wheel Top Running Bridge Cranes).**

- (a) If equalizing end trucks are used, the bridge girder and rigid end tie shall form a frame that is rigid about its vertical and horizontal (perpendicular to the rail) axes.
- (b) If compensating end trucks are used, the end tie shall be rigid about the vertical axis but relatively flexible about the horizontal axis to permit partial rocking motion for wheel load compensation.
- (c) End trucks shall be box section design with wheels centered between the webs.

2-1.3.1.4 **Bridge Girder-End Tie/End Truck Connections.**

- (a) The bolt holes and alignment holes should be located close to the webs of the structural member in widened flanges or welded-on flange extensions.
- (b) Additionally, if required to maintain rigidity in the horizontal plane, gusset plates may be required between the bridge girder and end tie/end truck flanges.
- (c) Tapered alignment pins (two per corner) shall be used to maintain original shop alignment between the bridge girders and the end ties/end trucks when reassembling the joint in the building. Alternatively, squaring marks permanently installed on the two girders may be installed in the shop to ensure original alignment of girders and end tie/end truck connections are maintained after field reassembly.
- (d) Access holes may be cut in the low stress areas of webs for bolt or nut installation and tightening.
- (e) Wheel axle bearing seats shall be designed so that wheel/axle bearing assembly can be removed with no more than 3 inches of jacking

- 2-1.4 **Design of Under Running Bridge Cranes. (Applicability includes commercial components)**
- (a) Crane bridge girders should be patented track type. Design criteria for these cranes shall follow MMA MH27.1.
 - (b) If structural steel bridge girders are used, design criteria for both welded box and single web type shall follow CMAA #74 and the additional requirements of this instruction.
 - (c) These two documents use different design approaches and their analyses and criteria shall not be intermixed.
 - (d) Unique requirements (such as test load cases), special features, and other items that are beyond the scope of CMAA #74 or MMA MH27.1 shall be addressed separately by the Navy Crane Center in the procurement specifications.

2-1.4.1 **Structural Components.**

2-1.4.1.1 **Bridge Girders.**

- (a) The recommended bridge girder design is the “patented track” type girder designed in accordance with MMA MH27.1.
- (b) Splices shall not be permitted in patented track.

2-1.4.1.2 **Runways.**

- (a) When splices are required due to length of runway sections, flat plates should be used on both sides of the upper T-section webs.
- (b) The lower T-section ends shall be aligned to minimize the gap on the running surface to not greater than 1/16” and not greater than a height difference of 1/32” for the wheel running surface alignment for a smooth crossing by the wheels.
- (c) Splices shall be located directly under roof structural support members.
- (d) A runway rail alignment is required for newly installed track.
- (e) When runways are suspended, bracing preventing damaging lateral or longitudinal movement is required. When flexible suspension systems are used with cranes utilizing rigid end trucks it is recommended for one runway to be installed without lateral bracing.

- (f) Loads transmitted to the building through the suspension shall have the review and approval of the building engineer of record (EOR) prior to installation.

2-1.4.1.3 **Extensions and Transfer Sections.**

- (a) Rail joints shall have both gap and vertical misalignment checked after assembly. See individual sections for alignment requirements.
- (b) For rails or structural support(s) designed to move or have adjustment, suitable interlocks are required to engage and lock the girders/rails in alignment during hoist/trolley transit.
- (c) When the adjacent bridge girder(s) cannot be brought into close proximity, a short transfer section shall be installed to span the separating distance.
- (d) On cranes whose hoist/trolley units transfer directly to another bridge girder, the end trucks should be located near the ends of the bridge girders to minimize the relative deflections at the gap.
- (e) Also, the adjacent runway tracks and the transfer section should be supported from a common structural member. This will help to maintain the alignment of the lower flanges for smooth wheel transit.
- (f) Limit switches shall be used to indicate when two bridge structures are properly aligned for trolley (carrier) transfer. In addition these limit switches shall prevent activation of the associated interlock system unless proper bridge alignment has been achieved.
- (g) Limit switches shall prevent disengaging the bridge interlock when the trolley position spans the bridge junction.
- (h) Limit switches shall activate an indication system that shows the operator the status of the interlock system including: when the bridges are not aligned; when the bridges are aligned; when the interlock is engaged; when the interlock is not engaged; and, prevent bridge disengagement if the interlock is not disengaged;
- (i) Limit switches shall slow the trolley to 10 percent of its rated speed as it approaches the trolley end stops and transitions through the bridge-to-bridge junction.
- (j) Where transferrable trolleys are used on an under running crane system, the trolley end stops shall be mechanically configured such that they can be disengaged only when a bridge is aligned to a mating bridge structure.

- (k) Where transferable trolleys are used and during the bridge-to-bridge transfer process with a rated load, the lower flange stresses shall be in accordance with the applicable standard for the entire length of the flange.

2-1.5 **Design of Wall Cranes, Jib Cranes, and Monorails. (Applicability includes commercial components)**

- (a) There are few industry design standards for any of the types of jib cranes or monorails. Individual components shall match those of bridge cranes (specifically booms, end ties/end trucks, and trolley frames) and comply with the design requirements of CMAA #70, CMAA #74, ASME B30.11, or MMA MH27.1.
- (b) Components peculiar to the specific configuration – such as pillars, foundations, tie rods, wall brackets, vertical frames, and anchor bolts – shall be designed in accordance with the AISC 360.

2-1.5.1 **Structural Components.**

2-1.5.1.1 **Cantilevered Booms.**

- (a) These booms are relatively short and, therefore, do not require any camber; however, the boom should be installed with a slight upward slope toward the tip to compensate for deflection under load.
- (b) The boom shall utilize specially designed trackage in accordance with MH 27.1, minimum Duty Class C, e.g., patented track beam, or rolled structural steel shape. If rolled structural shapes are used, sufficient calculations in accordance with CMAA #74, Section 3, shall be provided to prove the rated capacity of the boom.
- (c) Standard catalog items may be used for the column and boom support, and may be used at the manufacturer's rated capacity; however, maximum boom deflection with a capacity load suspended at the end of trolley travel shall not cause a deflection of the boom greater than 1/300 of the working boom length.
- (d) The design of the boom shall account for the dead weight of the intended hoist/trolley unit plus an impact load of ½ percent of rated load per foot per minute of hoisting speed, but not less than 15 percent.
- (e) The maximum allowable stress on the mast, boom, tie rod assembly, and mounting brackets shall not exceed 60 percent of the minimum yield strength of the material (CMAA #74, Table 3.4-1).

- (f) Standard cataloged devices for connection of the track to the indicated supporting structures may be used. If track manufacturer's cataloged devices are not utilized for this suspension system, complete shop drawings and calculations for each custom suspension device shall be submitted for review.

2-1.5.1.2 **Pillar Anchor Rods Bolts and Bases.**

- (a) Free-standing pillars require a base and anchor rods for securing them to a foundation, which is typically concrete. Provisions shall be made to transfer the column loads and moments to the footings and foundation using an analysis procedure consistent with the design of the structure.
- (b) Anchor rods shall be designed to provide the required resistance to loads on the completed structure at the base of the column including the net tensile components of any bending moment that may result from load combinations stipulated in ASCE/SEI 7 or other applicable building code. The anchor rods shall be designed in accordance with the nominal strength of fasteners and threaded parts found in Table J3.2 of AISC 360.
- (c) The design of column bases and anchor rods for the transfer of forces to the concrete foundation, including bearing against concrete elements shall satisfy the requirements of American Concrete Institute (ACI) 318 and ACI 349. ACI 318, Appendix D, provides design requirements for anchors in concrete used to transmit structural loads.
- (d) The preferred anchor rod installation method is cast-in-place. Installation of anchors into pre-existing foundations (post-installed anchors) shall follow the cracked concrete design in accordance with ACI 318, Appendix D.
- (e) Embedded ends of anchors should be terminated with heavy steel plates or washers with nuts on both sides.
- (f) Anchor bolts with bent ends (J or L bolts) are permitted only if recommended by the manufacturer of the standard commercial crane. Anchor bolt plates and washers shall be designed in accordance with ACI 318 Appendix D.

2-1.5.1.3 **Head Assembly**

- a) The head assembly shall support the boom beam atop the mast tube on a tapered roller bearing assembly which allows the necessary rotation.

- b) A self-aligning guide roller assembly shall support the radial load between the mast tube and lower portion of the head for pillar jibs.
- c) Guide rollers shall be ball or roller bearing mounted and shall make full contact with the roller race.
- d) An adjustment means shall be provided for leveling the boom.

2-1.5.1.4 **Mast Assembly**

- a) The mast assembly shall consist of a structural steel pipe, seamless steel tube, or rolled steel section.
- b) The mast shall be heavily gusseted to a steel flange base plate for pedestal type jib cranes, and fitted at the top with a center mounted bearing support.
- c) The mast shall be designed to support the boom in level position when the rated load is suspended at the end of the boom.

2-1.5.1.5 **Hinge Assembly**

- a) The hinge assembly for wall and column mounted jib cranes shall consist of steel hinge brackets, fittings and pins for mounting.
- b) The hinge brackets shall be designed for welded or bolted attachment to the supporting structure.
- c) Fittings shall be constructed with formed or fabricated steel and shall be designed so that all load carrying parts will be in double shear.
- d) Each fitting shall be designed and sized so that no bolt will be stressed beyond 20,000 pounds per square inch (psi) shear stress (AISC 360 allowance).
- e) Load carrying welds shall not be in tension.
- f) The boom web fitting and the upper pivot fitting shall turn on bearings and shall be provided with pressure lubrications fittings.
- g) Hinges shall be equipped with suitable thrust washers or thrust bearings.
- h) The hinge assembly shall enable rotation through the intended swing of the boom, but not less than 180 degrees.

2-1.5.1.6 **Tie Rod Assembly**

- a) The tie rod assembly shall consist of one or two diagonal tie rods, a top flange fitting and required clevises for connection of the upper hinge to the boom at a point which minimizes the largest deflection imparted to the beam when traversing the rated load the length of the beam.
- b) The tie rod shall be furnished with threaded adjustments which permit leveling of the boom.

2-1.5.1.7 **Foundations.** The foundation for the crane shall be in accordance with the equipment manufacturer's recommendations to ensure that the crane overturning moment is accommodated.

2-1.5.1.8 **Monorails.** The recommended monorail beam design is the "patented track" type beam designed in accordance with MMA MH27.1.

2-1.6 **Design of Portal Cranes.**

- (a) The design of most structural components of a portal crane is governed by main hoist operating load cases. Since portal cranes are capable of lifting a load in any number of positions (by rotating and luffing the boom), many different combinations of hook operating radii and rotate positions shall be considered in their design. Sideload forces may need to be considered if the rail structure has significant irregularities.
- (b) The major structural components of a portal crane's upper works (the boom, A-frame, strut, and machinery deck) are affected by the transmission of forces due to different positions of the boom.
 - 1. For a given load on the hook, the forces on these components may be calculated.
 - 2. For the full range of a crane's capability the loads and stresses should be determined in a minimum of 5 foot increments of radius.
 - 3. The stresses in each structural member and connection, in each of these components (the boom, A-frame, strut, and machinery deck) shall be considered.
 - 4. The designer shall use good judgment in determining which radii to use on each component, and on each member and connection in that component, in order to determine its adequacy under all operating conditions. To determine the stresses in every member and connection, in every structural

component, for every radius considered could be excessively time consuming.

5. Load design analysis should check the portal base for three orientations of the boom axis: parallel to the rails, perpendicular to the rails, and at the orientation that produces maximum corner load.
6. Each of these three orientations should be analyzed for two boom radii: the radius that produces maximum overturning moment on the portal base and the radius that produces maximum axial load on the portal base.
7. The load case of the boom at minimum radius with no load should be examined to see if a maximum overturning moment is developed (counterweight loading).
8. Each of the radius/orientation cases described above should be combined with the spreading forces, and, separately combined with the squeezing forces of the portal due to travel on curved track.

(c) Other load cases to be investigated for various areas of the crane.

1. The auxiliary hoist and whip hoist location and loadings govern the design of the boom section(s) beyond the main hook boom sheaves. Analysis should include their associated sheave supports and hoist foundations on the machinery deck.
2. The governing loads of the first boom section (boom foot) are usually governed by non-operating wind forces.
3. The rear portion of the machinery deck (counterweights, connections, stability) may be governed by the load case of the boom at minimum radius with no load, or with the boom removed for maintenance.

2-1.6.1 **Structural Components.**

2-1.6.1.1 **Lattice Booms.**

- (a) Tubular sections for structural members of booms are permitted, provided they are capable of being weld repaired in the field.
- (b) The ends of tubular sections shall always be seal welded to prevent water intrusion and corrosion.

- (c) The hinges on the lower section of the boom should be spread wider than the width of the basic boom structure to limit the wind loads and inertia loads on the hinges.
- (d) Hinge arrangements, which utilize bronze bushings, may be installed either in the boom foot section or the base supports.
- (e) Deflector sheaves, rubbing blocks, or rollers shall be provided as necessary to preclude wire rope contact with the boom structure.

2-1.6.1.2 **A-Frames.**

- (a) Pinned connections for A-frame members are required on new cranes.
- (b) A-frames shall include ladders and platforms for access to the various sheaves, sheave frames, equalizer beams, and other equipment.

2-1.6.1.3 **Machinery Decks.**

- (a) On new cranes the entire machinery deck should be a single weldment.
- (b) If practical considerations preclude this, then the bolted connections should be designed to ensure an accurate fit and alignment for field assembly.

2-1.6.1.4 **Main Beams.**

- (a) Rotate drives should be mounted adjacent to the main beams to take advantage of their inherent strength and rigidity.
- (b) On cranes with slewing ring (rotate) bearings, the main beams should include reinforced jacking points for raising the crane upper works to permit bearing replacement.

2-1.6.1.5 **Portal Bases.**

- (a) Box section construction on the lower portion of the gantry makes the portal bases rigid and provisions shall be made in the travel truck system to maintain wheel contact on uneven rails.
- (b) When required for overall crane stability, ballast in the form of concrete or steel may be placed near the bottom of the portal base structure.

- (c) The width of the portal base opening should be made as wide as the rail gauge permits
- (d) The height of the portal base opening should be not less than 22 feet.
- (e) Some portal cranes are required to traverse sharp curves, which impose large spreading or squeezing side loads and bending moments on the portal base.

2-1.6.1.6 Portal Base, Gantry, and Tube Penetrations.

- (a) Openings in these structures, such as doors and hatches, shall be reinforced around their perimeter with reinforcing rings (collars), structural frames, or doublers to maintain the section modulus (and strength) of the cross section. Openings should not have sharp corners, which could cause crack initiation from high stress concentration.
- (b) Any door or hatch into a closed space shall include positive means of opening from either side.
- (c) Exterior openings in horizontal surfaces shall have coamings or raised structural reinforcement to prevent entry of rainwater into the structure's interior.

2-1.6.1.7 Drive Foundations.

- (a) Drive foundations shall be rigid one-piece weldments designed to isolate the drive assembly from any deflections of the main support structures and to maintain alignment of the components. The foundations shall be independent of one another and installed by fasteners.
- (b) Travel drives, which are shaft (wheel axle) mounted, may only be pinned to the travel truck support structure.
- (c) See paragraph 2-5.3.i for diesel engine-generator foundation requirements.

2-1.6.2 Design Load and Maximum Allowable Stresses.

- (a) Structural design criteria for portal cranes are established by Navy Crane Center, and they reflect successful traditional practices of Navy crane designs tailored to the shipyard environment.

- (b) The following paragraphs prescribe the design load combinations and maximum allowable stresses for each structural component of portal cranes.
- (c) The maximum stress levels listed below represent the percentage of AISC 360 allowable values for the particular material.
 - 1. Boom, A-frame, Strut, Pendants, Machinery Deck and Hoist Foundations. The following load cases shall be considered:
 - i. Dead load, rated hook load with a vertical impact factor, 40 mph wind, and acceleration forces due to rotate and travel motion. The maximum stresses are limited to 85 percent of AISC 360 allowable values.
 - ii. Dead load and non-operating wind load from the front, rear, or side, with the boom at the specified radius. The maximum stresses are limited to 133 percent of AISC 360 allowable values for the particular material.
 - iii. Dead load, rated hook load, and extraordinary braking load. The maximum stresses are limited to 133 percent of AISC 360 allowable values
 - iv. For fatigue analyses: the stress range is defined as the algebraic difference between the stresses due to: (a) dead load plus 50 percent of the main hoist rated hook load, and (b) dead load with no hook load. If the crane is straight-line rated, the main hook will be at its maximum operating radius for this load case. If the crane is variably rated, the main hook will be at 75 percent of its maximum operating radius for this load case. (And the load will be 50 percent of main hoist rated capacity at that radius.) The maximum allowable stress range is limited to 100 percent of AISC 360 allowable values for Loading Condition 2 (that is, 100,000 to 500,000 cycles).

Additionally, this fatigue analysis is to be applied to the boom section between the whip hoist sheave and the main hoist sheave nest, using the dead load and 100 percent of the whip hoist rated hook load. On cranes with auxiliary hoists, this load case is also applied to the boom section between the auxiliary and main hoist sheave nests, using 75 percent of the auxiliary hoist rated hook load. (Normally whip and auxiliary hoists of variably rated cranes have constant ratings.) For both of these boom section analyses, the boom is assumed to be at 75 percent of each hoist's maximum operating radius.

- v. For the king pin analysis on roller path types of cranes only, dead load plus 150 percent main hoist rated load with a vertical impact factor. The maximum stresses are limited to 133 percent of AISC 360 allowable values.
2. Portal Base. The following load cases shall be considered:
 - i. Dead load, main hoist rated hook load with a vertical impact factor, 40 mph wind, acceleration forces due to rotate and travel motion, and spreading or squeezing forces. The maximum stresses are limited to 85 percent of AISC 360 allowable values.
 - ii. Dead load and non-operating wind load – from the front, rear, or side with the boom at the specified radius. The upper works is positioned with the boom in the specified direction. The maximum stresses are limited to 133 percent of AISC 360 allowable values.
 - iii. Dead load, rated hook load, and extraordinary braking load. The maximum stresses are limited to 133 percent of AISC 360 allowable values.
 - iv. For fatigue analysis: dead load with the boom at minimum operating radius. The stress range is defined as the algebraic difference between the stresses due to: (a) the boom directly over the section; and, (b) the counterweight directly over the section. The maximum allowable stress range is limited to 100 percent of the AISC 360 allowable values for Loading Condition 2 (that is, 100,000 to 500,000 cycles).
 - v. For fatigue analysis: the stress range is defined as the algebraic difference between the stresses due to the upper works load case defined in paragraph 2-1.6.2 (1.) (iii.), for the main hoist only. The maximum allowable stress range is limited to 100 percent of AISC 360 allowable values for Loading Condition 2 (that is, 100,000 to 500,000 cycles).
 3. Machinery House and Operator's Cab. The following load cases shall be considered:
 - i. Dead load, 40 mph wind, and a distributed roof load of 20 psf, or the local snow load, whichever is greater. The maximum stresses are limited to 100 percent of AISC 360 allowable values.

- ii. Concentrated downward load of 250 pounds at any location on the roof. The maximum stresses are limited to 100 percent of AISC 360 allowable values.
 - iii. Dead load, snow load, and non-operating wind load from any direction. The maximum stresses are limited to 133 percent of AISC 360 allowable values.
4. Other Structural Components. Structural components and members which are not specifically addressed above shall be designed according to the criteria to which they are related.

2-1.6.3 **Stability.**

- (a) The stability requirements defined below apply to straight-line rated cranes.
- (b) For variably rated cranes several hook load/radius combinations, at 5 to 10 feet increments, shall be used, in the stability cases defined below.

2-1.6.3.1 **Roller Path Designs.** For cranes with the upper works on a roller path and king pin assembly, the distance from the center of rotation to the resultant of all forces in the plane of the roller path shall be maintained within 90 percent of the roller path radius for two cases:

1. 130 percent of maximum load moment (maximum product of load multiplied by radius).
2. No load on the hooks, boom at its minimum operating radius, and 80 mph non-operating wind from the front.

2-1.6.3.2 **Slewing Ring (Rotate) Bearing Designs.** There are no stability requirements for the upper works on cranes with slewing ring bearings, provided that the bearing moment-carrying capacity is not exceeded.

2-1.6.3.3 **Entire Crane.**

- (a) The entire crane, of either roller path or slewing ring bearing design, is required to maintain overall stability for the following cases.
 1. 150 percent of maximum load moment on the crane (maximum product of load multiplied by radius). Rotate positions with the boom in line and perpendicular to the rails shall be considered. The resultant of all forces shall be within the rails (track gauge) or between the main gudgeon pin axes, as applicable.

2. Maximum load moment on the crane, and 40 mph operating wind from the rear of the upper works. Rotate positions with the boom in line and perpendicular to the rails shall be considered. The overturning moment shall not exceed 77 percent of the stabilizing moment.
3. No load on the hooks and the boom at its minimum operating radius. Rotate positions with the boom in line and perpendicular to the rails shall be considered. The resultant of all forces shall be within 60 percent of the distance from the crane's center of rotation to either rail or either main gudgeon pin axis, as applicable.
4. No load on the hooks, the boom at its minimum operating radius, and 80 mph non-operating wind from the front of the upper works. Rotate positions with the boom in line and perpendicular to the rails shall be considered. The overturning moment shall not exceed 80 percent of the stabilizing moment.
5. If the maximum wind gust velocity at the crane location is greater than 80 mph, the following stability check is required in addition to paragraph (4) above. With the crane positioned in its "storm wind stowed configuration", the overturning moment shall not exceed 80 percent of the stabilizing moment with a wind speed based on the maximum local operating wind velocity at the geographic location in accordance with ASCE/SEI 7.
 - (b) The resultant of all forces is translated to the plane of the tipping axis – either on the rails or through the main gudgeon pins.
 - (c) When the tipping axis is the rail, the maximum detrimental combination of travel truck float and wheel flange clearance on the rail head shall be included in the analyses.

2-1.7

Design of Floating Cranes.

- (a) Structural design criteria for the upper works of floating cranes are established entirely by the Navy Crane Center and parallel those of portal cranes.
- (b) For this reason, the major structural components of a floating crane upper works (the boom, A-frame, strut, and machinery deck) should be designed in the same manner as a portal crane upper works, as discussed in sections 2-1.6 and 2-1.6.2.
- (c) The structural design of the barge hull is governed by the standards of the American Bureau of Shipping (ABS) "Rules for Building and Classing of Steel Barges."

- (d) The tub supporting structure in the barge is affected by the radius of the boom, and by the orientation of the boom axis to the barge axis. The top of the tub structure shall be at least 7 feet above the barge deck to provide walking clearance and access to the slewing ring bearing or roller path assembly.
- (e) Several orientations of the boom axis should be considered in order to find the maximum load on each of the supporting members (usually bulkheads) in the barge.
- (f) Each of these boom axis orientations shall be analyzed for two boom radii: the radius which produces maximum overturning moment on the tub, and the radius which produces maximum axial load on the tub.

2-1.7.1 **Structural Components.**

2-1.7.1.1 **Lattice Boom.** See section 2-1.6.1.1. Additionally, boom designs on floating cranes shall consider the effects of side pulls due to allowable list and trim of the barge.

2-1.7.1.2 **A-Frames.** See section 2-1.6.1.2

2-1.7.1.3 **Machinery Deck.** See section 2-1.6.1.3

2-1.7.1.4 **Main Beams.** See section 2-1.6.1.4

2-1.7.1.5 **Drive Foundations.** See section 2-1.6.1.7

2-1.7.1.6 **Ballast.** Ballast is usually required on floating cranes.

2-1.7.2 **Design Load and Maximum Allowable Stresses.** The following paragraphs prescribe the design load combinations and maximum allowable stresses for each structural component of a floating crane. The maximum stress levels listed below represent the percentage of the AISC 360 allowable value for the particular material.

- (a) Boom, A-frame, Machinery Deck, Tub and Hoist Foundations. The following load cases shall be considered:
 - i. Dead load, main hoist rated load with a vertical impact factor, horizontal side load, and 40 mph wind. The maximum stresses are limited to 85 percent of AISC 360 allowable values.
 - ii. Dead load, 80 mph wind, and simultaneous maximum list and trim. This load case shall be applied to the boom at minimum operating radius and the wind from the front or

rear, boom at minimum radius and the wind from the side, the boom at maximum radius and the wind from the side. The maximum stresses are limited to 100 percent of AISC 360 allowable values.

- iii. Dead load, 145 mph wind, and dynamic effects due to pitch, roll, and heave. For this load case, the crane is assumed to be fully tied down (if tie-downs are provided), with the rotate locking device engaged and the boom secured in the boom rest. The maximum stresses are limited to 133 percent of AISC 360 allowable values.
- iv. Dead load, 150 percent main hoist rated load with a vertical impact factor. The crane is assumed to be level. This load case is applied only to the analyses of the king pin or hook rollers (if applicable) on roller path type cranes. The maximum stresses are limited to 133 percent of AISC 360 allowable values.
- v. Dead load, rated hook load, and extraordinary braking load. The maximum stresses are limited to 133 percent of AISC 360 allowable values.
- vi. For fatigue analyses, use the portal crane load case described in paragraph 2-1.6.2 (1.) (iii.). The maximum allowable stress range is limited to 100 percent of AISC 360 allowable values for Loading Condition 2 (that is, 100,000 to 500,000 cycles).

- (b) Boom Stops (and A-Frame). One load case is considered:

Dead load, main hoist rated load with the main hook 5.0 feet out from its minimum operating radius, and the barge level. The hook load is assumed to be suddenly released (lost) and the strain energy in the wire ropes and structural components is permitted to pull the boom towards the boom stops. If calculations indicate that contact is made with the boom stops, then the maximum stresses in the A-frame and the boom stops are limited to 100 percent of AISC 360 allowable values.

- (c) Tub. One additional load case is considered:

For fatigue analyses: dead load with the boom at minimum operating radius. The stress range is defined as the algebraic difference between the stresses due to: (a) the boom directly over the section; and, (b) the counterweight directly over the section. The maximum stress range in the tub and its connections to supporting structure in the barge shall be determined. The

maximum allowable stress range is limited to 100 percent of AISC 360 allowable values for Loading Condition 2 (that is, 100,000 to 500,000 cycles).

- (d) Other Structural Components. Structural components and members which are not specifically addressed above shall be designed according to the criteria to which they are related.
- (e) Barge Hull. The barge hull shall be designed according to the criteria of ABS and shall be submitted to that organization for review and approval.

Barge hull analysis includes the tub supporting structure, boom rest (supporting the weight of the boom), pilot house, and the cargo deck with a distributed load of 5000 psf (but not exceeding 1,000,000 pounds).

2-1.7.3 **Stability.**

- (a) The stability requirements defined below apply to straight-line rated cranes.
- (b) For variably rated cranes, several hook load/radius combinations, at 5 to 10 foot increments, shall be used, in the stability cases defined below.
- (c) For each case three rotate positions shall be considered – boom forward, aft, and over the side.
- (d) Boom angles are set to correspond to the required hook radii when the barge is level, before the effect of the actual maximum list and trim angles is applied.

2-1.7.3.1 **Roller Path Designs.** Except for the inclusion of the list and trim effects, the same cases as in paragraph 2-1.6.3.1 are required for the upper works

2-1.7.3.2 **Rotate Bearing Designs.** There are no stability requirements for the upper works on cranes with rotate bearings, provided that the bearing moment-carrying and radial capacities are not exceeded. In addition to list and trim effects, the inherent oscillating motion of floating cranes during nonuse periods shall be taken into account when determining the required rating of the rotate bearing.

2-1.7.3.3 **Entire Crane.**

- (a) For normal operation, the crane (barge) with or without the maximum deck load, with the upper works in any position, with any load (up to rated capacity) on any hook at any radius within its operating range, and with the water ballast compartments full or

empty, the barge shall remain within the limits listed below. (The center of gravity of the deck load is assumed to be 5.0 feet above the level of the cargo lay-down area.)

1. Maximum list of 5.0 degrees. See paragraph 2-1.7.3.4.
2. Maximum trim of 5.0 degrees. See paragraph 2-1.7.3.4.
3. Minimum freeboard of 2.5 feet at the lowest point, at combined list and trim angle.
4. Minimum transverse metacentric height (GM) of 35 feet.
5. Residual dynamic stability of not less than 15 foot-degrees between the curve of static stability and the heeling arm curve. This stability is taken between the heeling arm equilibrium point (list angle) of maximum ordinate differences between the two curves, but not exceeding 40 degrees. (However, protection against down-flooding is required to 40 degrees of heel.)
6. Sufficient dynamic stability to prevent capsizing in case of sudden loss of the hook load of any hoist, including test loads of 130 percent of rated capacity. Specifically, the righting arm area (foot-degrees) on the crane counterweight side shall be adequate to absorb the energy imparted to the entire crane by the sudden loss of the rated hook load.

(b) For overload tests with 130 percent rated capacity on any load hook, with no deck load, and with the most adverse upper works rotate position and boom angle, the barge shall remain within these limits:

1. Minimum freeboard of 1.0 foot at the lowest point, at combined list and trim angle.
2. Upper bilge tangent, adjacent to any flat bottom area, completely under water.

2-1.7.3.4 Recommended List and Trim. The list and trim values, in paragraph 2-1.7.3.3, meet ASME B30.8 requirements for all types of floating cranes. However, these values may result in excessive load drift under certain circumstances. Existing Navy floating cranes, especially the newer designs, have relatively long booms and high boom hinge pin elevations (above the waterline.) An increase in boom length or boom hinge pin elevation will cause the load to drift farther for a given amount of list. The list and trim values in Table 2-3 are recommended for satisfactory load handling, based on the performance of existing Navy floating cranes.

Table 2-3 Recommended List and Trim Angles for Floating Cranes

Main Hoist Upper Block Elevation* (feet)	List Angle (degrees)	Trim Angle (degrees)
120	4.0	2.7
140	3.6	2.4
160	3.3	2.2
180	3.0	2.0
200	2.7	1.8
220	2.5	1.7

* The elevation of the main hoist upper block above the waterline, with the boom at minimum radius and the barge assumed to be level.

2-1.7.3.5 Towing Configuration.

- (a) For towing, the boom is secured in the boom rest and there is no deck load. Tie down fittings and a tie down plan shall be provided.
- (b) The water ballast compartments (if applicable) are used to obtain the required trim.
- (c) For this towing configuration, three cases shall be considered:
 1. Minimum freeboard of 5.0 feet.
 2. For towing in protected waters, minimum trim of 2.0 inches down by the stern.
 3. For towing on the open seas, minimum trim of 1.0 foot down by the stern.

2-1.8 Design of Container Cranes.

- (a) The following structural design criteria for container cranes are derived from informal standards of industry, port authorities, and engineering firms specializing in the design of these cranes.
- (b) In the load combinations described below, all loads shall be applied simultaneously on the most adverse crane configuration.
- (c) In lieu of the load combinations described below, the FEM "Rules for the Design of Hoisting Appliances" may be used, subject to Navy Crane Center approval.
- (d) When analyses include secondary (P-delta) effects due to elastic deformation of the structure and joint flexibility, the maximum allowable stresses may be increased by a factor of 1.2, provided

that the structure conforms to the stress limits when the secondary effects are not considered.

- (e) For fatigue analyses, however, the secondary effects shall be considered but with no increase in the maximum allowable stresses.
1. Entire Structure (Operating Configuration). In this condition, the boom is horizontal and supported by the boom stays. The following load cases shall be considered for normal and overload conditions:
 - i. Dead load, trolley dead load, live load (container weighing 89,600 to 112,000 pounds), lift system weight (head block, spreader, wire ropes, and sheaves), skewing force couple (5 percent of the gantry maximum wheel loads), and 150 percent of acceleration/deceleration forces (due to gantry or trolley travel). The center of gravity of the container is assumed to be eccentric by 10 percent from its geometric center in the longitudinal and transverse directions (4.5 feet on a 45-foot long container, and 0.8 feet on an 8-foot wide container).

The skewing forces are applied to the wheel flanges (perpendicular to the rails). The forces due to gantry travel shall be at least 5 percent of the total crane weight, including the container weight, and are applied in the direction of gantry travel; additionally, 25 percent of that force is applied perpendicular to the direction of travel. The maximum stresses are limited to 90 percent of the AISC 360 allowable value.

- ii. Dead load, trolley dead load with a 10 percent vertical impact factor, live load plus lift system weight with a 30 percent vertical impact factor, trolley lateral load, and a 55 mph operating wind applied in the most adverse direction.

The trolley lateral load due to its acceleration/deceleration on the boom and main beams is calculated on the basis of the trolley drive motor and brake characteristics but shall be at least 10 percent of the trolley dead load, live load, and lift system; additionally, 25 percent of that force is applied perpendicular to the direction of travel. The maximum stresses are limited to 90 percent of AISC 360 allowable values.

- iii. If the crane is equipped with a load beam: dead load, trolley dead load, load beam rated load plus load beam lift system

weight with a 30 percent vertical impact factor, and operating wind load. The rated load is assumed to be at the geometric center of the load beam. The maximum stresses are limited to 90 percent of AISC 360 allowable values.

- iv. Dead load, trolley dead load, lift system weight (head block, spreader, wire ropes, and sheaves), snag force, and operating wind load. The maximum stresses are limited to 135 percent of AISC 360 allowable values.
- v. Dead load, trolley dead load, live load, lift system weight, operating wind load, and collision force. The maximum stresses are limited to 135 percent of AISC 360 allowable values.
- vi. Dead load, trolley dead load, live load, lift system weight, and seismic load. The maximum stresses are limited to 135 percent of AISC 360 allowable values.
- vii. For fatigue analyses: dead load, trolley dead load, lift system weight, average live load, and trolley lateral load. The stress range is defined as the algebraic difference between the maximum and minimum stress at a point during one load cycle.

Average live load is taken as 75 percent of the fully loaded container. One load cycle is defined as: hoisting the container from the pier, traveling the trolley and setting the container on the ship, hoisting the empty spreader and traveling the trolley to the pier, and setting the spreader on a container. Alternatively, the reverse sequence may be used. For container terminals with no pier storage areas, trolley travel range is taken as 75 percent of the maximum outreach (measured from the waterside rail) to centerline of the gantry. For container terminals with pier storage of containers, trolley travel range is taken as 75 percent of the maximum outreach (measured as above) to 75 percent of the maximum backreach (measured from the land side rail). Secondary effects due to elastic deformation of the structure shall be considered in this analysis. The maximum stress ranges are limited to 100 percent of AISC 360 allowable values for Loading Condition 4 (that is, over 2,000,000 cycles).

- viii. For lateral deflection perpendicular to the boom: gantry lateral load. The lateral deflection perpendicular to the boom is limited to $h/240$, where h is the vertical distance from the

rail to the connections between the main girders and the transverse girders.

- ix. For lateral deflection parallel to the boom: 300 percent of trolley lateral load. The lateral deflection parallel to the boom is limited to $h/1400$, where h is the vertical distance from the rail to the connections between the main girders and the transverse girders.
2. Entire Structure (Stowed Configuration). In this configuration, the boom is secured in its raised position, and the trolley is locked in its stowed location. The following load cases shall be considered:
 - i. Dead load, trolley dead load, lift system weight, and non-operating wind load. The wind load is applied in the most adverse direction. The maximum stresses are limited to 126 percent of AISC 360 allowable values.
 - ii. Dead load, trolley dead load, lift system weight, and seismic load. The maximum stresses are limited to 126 percent of AISC 360 allowable values.
 3. Other Structural Assemblies and Components. The machinery house, diesel engine-generator enclosure, operator's cab, boom control station, stairs, walkways, platforms, and ladders shall be designed according to the criteria for similar assemblies and components of portal cranes, as described above in paragraph 2-1.6 and sub-paragraphs.

2-1.8.1 **Structural Components.**

2-1.8.1.1 **Boom.**

- (a) The boom design shall be twin welded steel girders with box sections and bolted field splices. The boom girders' cross sections shall be sufficiently large to permit entry into their interior and are reinforced with open diaphragms to permit full access for inspection or repair.
- (b) The boom girders shall be supported by stays at the outer ends and hinged at the heel so that they can be raised with a wire rope hoisting system to a minimum 80 degree vertical position to clear the ship's superstructure during travel or for storage.
- (c) The boom and mating structures shall be equipped with a latch to retain the boom in the upright position and an auxiliary pin/structure to support the boom in case of heel pin failure.

- (d) The boom shall include or support a full-length walkway arranged to permit emergency egress from the cab anywhere along the walkway.
- (e) The boom shall be equipped with weather tight access hatches to allow inspection of the interior of the girders.
- (f) The boom structure in conjunction with the boom hoist shall be designed for hoisting with one set of falls in the event the other set fails. The design load shall include the effect of shock loading due to one rope breaking. The allowable stress shall be 1.5 times the basic allowable stress.

2-1.8.1.2 **Main Beam.** The main beam may be considered as an extension of the boom.

- (a) The main beam shall extend backwards through the gantry to permit trolley travel past the land-side rail. The main beam's design shall be twin welded steel girders with box sections. The cross sections shall be sufficiently large to permit entry into their interior and are reinforced with open diaphragms to permit full access for inspection or repair
- (b) The main beam shall provide support for the machinery house, engine house, drive mechanisms, and electrical equipment.
- (c) The main beam shall include or support a walkway that matches the boom walkway and extends to the end of the main beam. This walkway shall permit emergency egress from the cab at any location
- (d) The other side of the main beam shall have a short walkway or platform at the back end for servicing the festoon system.
- (e) The two walkways shall be connected by a crossover footwalk.
- (f) The main beam shall be equipped with weather tight access hatches to allow inspection of the interior of the girders.

2-1.8.1.3 **Gantry Structure.**

- (a) See section 2-1.6.1.5, portal base. Additionally, the gantry shall be equipped with continuous internal passageways with ladders or walkways necessary for inspection and maintenance.
- (b) All field splices shall be bolted.
- (c) The gantry structure shall be equipped with weather tight access hatches to allow inspection of the interior of the gantry structure.

2-1.8.1.4 **A-Frames.** See section 2-1.6.1.2. On container cranes, however, the A-frames are not required to be pinned but may be integral vertical extensions of the gantry structure.

2-1.8.1.5 **Boom and Main Beam Stays.**

- (a) The boom and main beam stays shall be rigid structural members that shall fully support the boom and main beam in their horizontal operating position without relying on support from the boom hoist wire ropes.
- (b) The boom stays shall be hinged in a manner to avoid interference with any part on the crane.
- (c) When the boom is in the upright position the boom stays shall be designed to fold and be stowed in a rack or saddle structure on the boom.

2-1.8.1.6 **Machinery Deck.** See section 2-1.6.1.3

2-1.8.1.7 **Drive Foundations.** See section 2-1.6.1.7

2-1.8.1.8 **Ballast.**

- (a) Acceptable materials include plain concrete and steel plate. Earthen material such as rock, sand or gravel shall not be used. Liquids shall not be used.
- (b) Ballast shall be enclosed in a weatherproof steel box and seal welded.
- (c) Ballast placement shall not obstruct or conceal critical structural members or other items requiring maintenance or inspection.

2-1.8.1.9 **Trolley.**

- (a) The trolley frame shall have sufficient torsional flexibility to allow the individual wheel reactions to equalize and share the load.
- (b) Drop lugs shall be provided to support the trolley and limit the drop to 1 inch in case of axle or wheel failure. Jacking lugs shall be provided to allow axle replacement at any point of trolley travel. Trolley design shall allow horizontal removal (parallel to rail) of wheel and axle assemblies.
- (c) A positive means shall be provided to prevent trolley wheels from lifting off the rails. A stowed position locking device and locking

pins shall be provided for the design stowed wind condition and stowed trolley position.

- (d) Trolley sweeps shall be provided and designed to remove debris from the trolley rail.

2-1.8.1.10 **Trolley Rails.**

- (a) Rails shall be selected and installed in compliance with FEM 1.001. Rail size selected shall allow maximum calculated trolley wheel load. Rails shall be of DIN or ASCE specifications.
- (b) Rail material shall be equivalent to ASTM A-759 and heat treated to 320-390 Brinell Hardness Number (BHN).
- (c) Rail sections on each side of the hinge shall be directly supported on machined surfaces of the rail support beam. The rail supports shall be designed to transmit maximum wheel load across the rail joint and shall not affect the load on the hinge bearing.

2-1.8.2 **Stability.** The following load cases shall be considered for container crane stability in the operating (boom horizontal) and stowed (boom raised and secured) configuration.

2-1.8.2.1 **Operating Configuration.**

- (a) Container cranes in their operating configuration shall be analyzed with the trolley at its maximum outreach and maximum backreach.
- (b) The resultant of all forces is translated to the plane of the tipping axis – either on the rails or through the main gudgeon pins.
- (c) When the tipping axis is the rail, the maximum wheel flange clearance on the rail head shall be included in the analysis. (Normally container cranes operate on straight track and have no travel truck float.)
- (d) The resultant of all forces shall be within 95 percent of the distance from the crane's geometric center to either rail or the main gudgeon axis, as applicable.
- (e) The following load cases shall be considered:
 1. Dead load, trolley dead load, 200 percent of the live load (container weighing 89,600 to 112,000 pounds), lift system (head block, spreader, wire ropes, and sheaves), and 55 mph

operating wind applied from either end, and perpendicular to the boom.

2. Dead load, trolley dead load, live load, lift system, and collision force.
3. Dead load, trolley dead load, live load, lift system, and seismic load.

2-1.8.2.2 **Stowed Configuration.**

- (a) In the stowed configuration the boom is raised and locked against the A-frame boom stops, the trolley is locked on the main beams near the land side gantry leg, but the gantry is not tied down.
- (b) The resultant of all forces shall be within 80 percent of the distance from the gantry's geometric center to either rail or the main gudgeon axis, as applicable.
- (c) The following load cases shall be considered:
 1. Dead load, trolley dead load, lift system, and non-operating wind load.
 2. Dead load, trolley dead load, lift system, and seismic load.

2-1.9 **Design of Mobile and Articulating Cranes.**

- (a) Structural design criteria for mobile cranes shall follow the American Society of Mechanical Engineers (ASME) and Society of Automotive Engineers (SAE) standards noted below, which are observed by commercial firms that manufacture such cranes. They include analytical methods and non-destructive testing of the entire load-supporting structure of the crane under static conditions.
- (b) The following SAE standards apply:
 1. J1093. Booms ratings developed according to this procedure shall be verified by testing described in J987.
 2. J987. The test is performed on an instrumented crane and approximates the maximum loading conditions on all its structural components. The maximum allowable stresses and deflections are specified.
 3. J1063. This test is similar in scope and methodology to J987.
 4. J1078. This standard serves as a supplement to J1063.

- (c) The following ASME standards apply:
 - 1. B30.5. Mobile and Locomotive Cranes. This standard includes category 4 commercial truck mounted cranes.
 - 2. B30.22. Articulating Boom Cranes. This standard includes stationary articulating boom cranes.

2-1.9.1 **Stability.**

- (a) Stability criteria for mobile cranes (and locomotive cranes) are detailed in ASME B30.5, B30.22, and NAVFAC P-307; they address the margins of stability and determination of load ratings for various crane configurations and site conditions.
- (b) Additional requirements for test apparatus, set-up, and test methods are provided in SAE J765.
- (c) For Special Purpose Service (SPS) applications, specific local restrictions (in the form of policies and procedures) are usually imposed (also see section 2-7.1).

2-1.10 **Design of Gantry and Semi-Gantry Cranes.**

- (a) These cranes, being similar to bridge cranes, shall be designed according to the criteria of CMAA #70 and CMAA #74, as applicable.
- (b) Equalized ground-level travel truck frames shall be designed as portal crane components, but for the load cases of CMAA #70.

2-1.10.1 **Structural Components.**

2-1.10.1.1 **Bridge Girders.** See section 2-1.3.1.1

2-1.10.1.2 **Ballast.** See section 2-1.8.1.8

2-1.10.2 **Stability.**

- (a) These cranes may be designed with either a load block and hook for general applications, or with a head block and spreader for container handling. (Semi-gantry cranes are not normally used for container handling.)
- (b) The resultant of all forces is translated to the plane of the tipping axis.
- (c) The following load cases shall be considered:

1. General Applications. For cranes with a load block:
 - i. Dead load, trolley with rated hook load in any position on the bridge girders, and 40 mph operating wind applied perpendicular to the bridge girders. The resultant of all forces and moments shall be within 70 percent of the distance from the crane's geometric center to the main gudgeon pin axis.
 - ii. Dead load, trolley with no hook load in any position on the bridge girders, and non-operating wind load applied perpendicular to the bridge girders. The resultant of all forces and moments shall be within 80 percent of the distance from the crane's geometric center to the main gudgeon pin axis.
 - iii. Dead load, trolley with rated hook load in any position on the bridge girders, and collision force. The resultant of all forces and moments shall be within the main gudgeon pin axes.

Note: In the case of semi-gantry cranes, the crane configuration is assumed to be that of a gantry crane (symmetrical to the gantry end of the crane).

2. Container Handling. Stability cases and stability requirements for cranes with a head block are identical to those in paragraph 2-1.3.5. 1., except that the total weight of head block, spreader, and container is used in place of "rated hook load" and only the weight of head block is used in place of "no hook load."

2-1.11 **Supplementary Design Features.** Additional structural design features shall be considered and included in the original design to enhance the safety, permit efficient field assembly, and facilitate the maintainability of cranes.

2-1.11.1 **Personnel Safety Requirements. (Applicability includes commercial components)**

- (a) The arrangement, design, and sizing of safety features are mandated by several Occupational Safety and Health Administration (OSHA) standards and interpretation letters, ASME standards, ANSI/ALI 14.3, ANSI/ASSE A1264.1, and NFPA codes. Fixed ladders over 20 feet in length should be equipped with a ladder climbing device (LCD). The ladder strength shall be adequate for the LCD system.
- (b) The requirements in the following paragraphs are supplemented with specific Navy requirements, and compiled according to the subject.

2-1.11.1.1 **Accessibility Provisions.**

- (a) Operator's cabs, machinery houses, bridge footwalks, platforms, booms, A-frames, crane lubrication points (e.g., daily, weekly, monthly lubrication points), and crane lighting fixtures, shall be accessible without the use of safety harnesses or other extraordinary means.
- (b) Lubrication points shall be accessible without having to be on a ladder (except for underhung components).
- (c) Step-over gaps shall not be wider than 12 inches.
- (d) Footwalks shall be free of obstructions that may jeopardize personnel by movement of the crane.
- (e) When there is relative movement between adjacent structures, the transit between them shall be arranged to ensure that a safe path is maintained throughout the entire range of orientations.
- (f) Footwalks shall also be free of exposed hazardous moving parts and electrical components that may injure personnel.
- (g) Self-closing swinging gates or hinged hatch covers are required to close openings that expose a drop to a lower level of more than 4 feet along the passageway.
- (h) Headroom directly above a walkway shall be at least 48 inches.
- (i) When it is necessary to climb more than 120 feet of elevation to reach the operator's cab or machinery deck, consideration should be given to providing a powered means of access in addition to the ladders or stairs.
- (j) Portal and floating cranes shall be provided with circular platforms on their portal bases around the roller path or slewing ring bearing. The platform and ladders extending from the upperworks shall have full-height smooth sheet covers inside the standard railing as guards against pinch points. The gap between the sheet cover and the rotating ladder shall be less than 1.0 inch.

2-1.11.1.2 **Working Clearances for Electrical Equipment.**

- (a) The doors of electrical equipment shall be removable or swing open at least 90 degrees.

- (b) When there are exposed live parts on one side and no live or grounded parts on the other side of the workspace, or exposed live parts on both sides effectively guarded by suitable insulating material, at least 36 inches of clearance shall be provided for nominal voltage to ground of 0-600 volts.
- (c) When there are exposed live parts on one side and grounded parts on the other side of the workspace, at least 36 inches of clearance shall be provided for nominal voltage to ground of 0-150 volts, and at least 42 inches for 151-600 volts.
- (d) When there are exposed live parts on both sides of the workspace (not effectively guarded), at least 36 inches of clearance shall be provided for nominal voltage to ground of 0-150 volts, and at least 48 inches for 151-600 volts.
- (e) Working space in the direction of access to live parts that are likely to require inspection, adjustment, servicing or maintenance, including all bridge mounted control panel enclosures or switching devices, shall be a minimum of 30 inches. In addition, the work space in front of the enclosure shall be at least as wide as the enclosure and shall not be less than 30 inches wide.
- (f) At least one entrance of sufficient area shall be provided to give access to and egress from the working space about electrical equipment.
- (g) The clearances are measured from the live parts if they are exposed or from the enclosure front or opening if the parts are enclosed. (Insulated wire or insulated busbars operating at not over 300 volts are not considered live parts.)
- (h) For cranes built prior to April 16, 1981, clearances from exposed live parts shall be at least 30 inches.

2-1.11.1.3 **Machinery Guards.**

- (a) Exposed moving parts, either rotating or reciprocating, which might constitute a hazard under normal operating conditions, shall be provided with guards. Couplings with exposed bolts or nuts (non-safety type) and open gearing are the most common examples of such parts.
- (b) The guards shall be securely fastened and capable of supporting, without permanent deformation, a weight of 200 pounds unless the guard is located where it is impossible for a person to step on it.

2-1.11.1.4 **Anchorage.**

- (a) When anchorages are specified for personal fall arrest equipment, they shall be designed in accordance with ANSI Z359 Fall Protection Code standards.
- (b) Anchorages are recommended to provide access to all points of the trolley on top running trolleys.

2-1.11.1.5 **Signage.**

- (a) Signs are classified according to use.
- (b) *Danger* signs shall be posted to warn of specific dangers.
- (c) *Caution* signs shall be posted to warn against potential hazards.
- (d) *Safety instruction* signs shall be posted where there is a need for general instruction and suggestions relative to safety measures.

2-1.11.1.6 **Emergency Illumination.**

- (a) An emergency lighting system is required in each machinery house module and individual diesel engine compartment of portal, floating, and container cranes.
- (b) The system shall be so arranged that the failure of any individual lighting element, such as the burning out of a light bulb, cannot leave any space in total darkness.
- (c) Emergency lighting facilities for means of egress shall be provided for passageways, platforms, ladders, and stairs leading to an exit.
- (d) Adequate and reliable illumination shall be provided at all exit facilities.
- (e) Bridge and gantry or semi-gantry cranes do not require emergency illumination if located inside a building with its own automatic emergency lighting system.
- (f) If the building does not have such a system, then it shall be provided on the crane or the egress path from the operator's cab and footwalks shall be marked with luminescent directional (arrow like) indicators securely fastened to the crane structure.

2-1.11.1.7 **Building Interface.**

- (a) Bridge crane accessibility should include the host building.
- (b) For existing buildings where the accessibility provisions do not comply with these requirements, their modification or replacement (within the constraints of the building configuration and its installed equipment) may be included in the crane acquisition contract; alternatively, the Navy activity may schedule such remedial work under its own, separate contract.

2-1.11.2 **Test Weights.**

- (a) In the case of container cranes, the test weight(s) shall be designed for engagement by the spreader twist locks to duplicate the operational loading of the spreader.
- (b) Dedicated test weights should be considered for specialized crane designs or hard to reach locations..
- (c) When test weights are specified see NAVFAC P-307 for requirements.

2-1.11.3 **Structural Assembly Standards.**

- (a) Common acceptance criteria for dimensional tolerance for structural steel are established by ASTM A6. This standard addresses the permissible variations in the dimensional attributes of commercially produced structural steel. Field assembly and fit-up of large structural components should be in accordance with AISC 303.
- (b) Additionally, although this item is not addressed by AISC 360, on new cranes filler plates are acceptable at bolted butt joints, such as those between boom sections, portal base cap and legs, A-frame members, and other major structural joints. The minimum thickness of the filler plates is 1/4 inch. Only one filler plate is permitted per bolted butt joint.

2-1.11.4 **Accessibility and Maintainability Features.** New cranes require specific designed-in accessibility and maintainability features.

- (a) The layout of the machinery house on portal, floating, and container cranes requires that the diesel engine-generator set be separated from the control (electrical) compartment and operator's cab by the hoist machinery compartment. This arrangement isolates the

electrical equipment and operator from the noisy and oil/fuel contaminated power compartment.

- (b) The boom and boom walkway shall be comprised of sections of manageable lengths suitable for lifting.
- (c) Platforms and ladders are required for access to both sides of all sheaves and sheave nest pins, and all lighting fixtures.
- (d) The boom walkway shall be accessible with the boom horizontal (or other specified maintenance position).
- (e) The A-frame connection to the machinery deck shall be by means of structural pins and outboard of the machinery house.
- (f) The A-frame front and back legs shall also be pinned at their apex and a pinned brace installed between them to prevent their folding when lifted from the machinery deck.
- (g) Stairs, ladders, and platforms shall be provided for access to all sheave and pin maintenance points.
- (h) Lifting padeyes shall be provided to permit removal of the entire A-frame as a unit.
- (i) The counterweight shall be all steel and pinned or interlocked with the main beams of the machinery deck.
- (j) The counterweight shall be segmented so that segments can be removed to maintain crane stability when the boom is removed. Each segment shall include lifting padeyes for easy removal and reinstallation.
- (k) Roofs over the power and control compartments shall be removable as one-piece units or in large sections. With either arrangement, the roof openings shall be adequate to lift out the diesel engine-generator set, as a unit on its foundation, or any electrical control cabinet.
- (l) The roof over the hoist machinery compartment (underneath the A-frame) shall include removable access hatches to facilitate removal of major hoist drive components (including the wire rope drums), rotate drives (preferably as complete units), and the collector ring assembly.
- (m) Roof walkways and hand railings shall be terminated at the lines of separation of the roof sections, and each is to be removable (by unbolting) from its roof section.

- (n) Access hatches shall be weathertight, openable from both sides, and provided with shielded grills for ventilation.
- (o) The machinery house structure and the A-frame should be equipped with padeyes for maneuvering/transporting these components to the access hatches.
- (p) Complete hoist drives on their foundations shall be removable after the removal of the A-frame and the hoist machinery compartment roof.
- (q) The hoist drive foundations shall include padeyes for the purpose of removal.
- (r) Both ends of all internal and external rotate bearing bolts or studs shall be accessible for tensioning and retensioning.
- (s) The size of the hydraulic tensioners shall be confirmed to ensure adequate space for their connection to the bolts or studs.
- (t) The top of the portal base and the underside of the machinery deck shall include provisions for jacking-up of the upper works and removal of the rotate bearing.
- (u) Travel truck drives shall be removable (as a unit) from the travel truck frames.
- (v) The preferred connection to the wheel axle is by means of a compression sleeve or a spline. If the wheel axle is pressed and keyed into a hollow output shaft of a speed reducer, the assembly shall include provisions for pressing out the wheel axle.
- (w) Interiors of large closed structural sections – such as portal bases, machinery decks, gantries, and container crane main beams or boom girders – shall be accessible for inspection and maintenance. Accessibility provisions include ladders, platforms, and lighting.
- (x) Brakes shall be designed, selected, and installed such that they may be inspected for proper settings and adjustments without disassembly of the brake or other components (other than covers).
- (y) Lubrication points and frequency should be minimized to the maximum extent possible. Lubrication points shall be accessible without requiring fall protection.

2-1.11.5 **Coatings.**

2-1.11.5.1 **Painting and Corrosion Protection.**

- (a) Steel surfaces exposed to the atmosphere, whether indoors or outdoors, require painting for protection against corrosion. (Interior surfaces of sealed spaces and voids may be left unpainted.)
- (b) To obtain the full life of any paint system, the steel surface shall be properly prepared and the primers should contain zinc (in the form of dust of organic or inorganic zinc compounds) for rust inhibition by the galvanic process.
- (c) Major Navy activities have their own preferred paint systems, which should be followed if their performance has been satisfactory.
- (d) Other activities should consult with Navy Crane Center for the level of surface preparation and selection of the paint system.
- (e) Bolts, nuts, and washers in exterior structural connections should be cleaned, primed, and top coated after installation and shall be in accordance with RCSC Specification for Structural Joints Using High-Strength Bolts”.
- (f) The primer used should be compatible with the surface preparation and the topcoat.
- (g) Primers on faying surfaces of structural bolted connections shall meet the requirements of the RCSC Specification for Structural Joints Using High-Strength Bolts. Such paint protection is appropriate for all service environments, but are intended mainly for use in conditions of high humidity or marine atmosphere.

2-1.11.5.2 Painting and Corrosion Protection of Structural-Mechanical Components. Structural-mechanical components (described in section 2-2) should be painted for corrosion protection in the same manner as structural components, described in paragraph 2-1.11.5.1 – but with the following exceptions:

- (a) Working surfaces – those subjected to rolling, sliding, or pivoting motion – shall be left unpainted. (The relative motion with mating surfaces, and periodically applied lubrication, prevent corrosion on them. Various pins, roller treads, rail and roller path running surfaces are in this category.)
- (b) Corrosion resistant metals and plating should be left unpainted. (Stainless steel, copper alloys, aluminum, galvanized wire rope pendants, and chrome plated steel pins are in this category.)

- (c) Lubrication fittings shall be left unpainted.
- (d) Rotate bearing bolts, studs, and nuts shall be left unpainted. (These items require periodic inspections and checks of their tension.)
- (e) Non-structural fasteners, such as keeper bar retainer fasteners, should be painted without blast cleaning.

2-1.11.5.3 Painting and Corrosion Protection of Mechanical and Electrical Equipment. Electrical and mechanical components should be painted for corrosion protection in the same manner as structural components, described in paragraph 2-1.11.5.1 – but with the following exceptions:

- (a) Steel panel enclosures received in unpainted condition shall be painted in accordance with paragraph 2-1.11.5.1.
- (b) Enclosures fabricated from stainless steel shall not be painted.
- (c) Other than aluminum that has not been anodized, nonferrous metals shall not be painted.
- (d) Motors used in outdoor applications shall be factory painted to their manufacturer's standard for "wash-down" service.
- (e) Prior to painting, galvanized rigid steel conduit shall be sprayed with a zinc-phosphate primer.
- (f) Gaskets of enclosures and fixtures, and joints and contact surfaces of explosion-proof and dust-ignition-proof enclosures shall be kept free of any paint to prevent damage during removal and reinstallation of gaskets of enclosures.
- (g) The following surfaces and materials of mechanical components shall not be painted:
 - 1. Working surfaces of wire rope drums, sheaves, rails and patented track, wheel and roller treads, etc.
 - 2. Wire ropes, hooks, and hook nuts. (These items are periodically lubricated or have a preservative applied.)
 - 3. Threaded portions of components intended for making adjustments or changing settings.
 - 4. Contact surfaces underneath assembly and mounting fasteners (except for a primer coating).

5. Corrosion resistant metals and plating; such as stainless steel, copper alloys (bronze), aluminum, and chrome or nickel plating.

Whenever an off-the-shelf component is supplied with options for paint or surface preparation, it is recommended to obtain the highest quality option.

2-1.11.5.4 **Cathodic Protection for Floating Crane Barges.**

- (a) The system shall have sufficient capacity to supply a minimum current density of 2 milliamperes per square foot to the immersed barge area.
- (b) The minimum distance between any anode and reference cell should be 40 feet.

2-1.11.6 **Glazing.**

- (a) All cab and machinery house glazing shall be safety-glazing material, as defined in SAE Z26.1 with the exception that wired glass and plastic is prohibited for the cab glazing material.
- (b) Operator's cab front and lower panels shall be clear glass, and installed in a manner that can withstand a load of 200 pounds applied to the glass unless other loading conditions increase the loading on the glass. This applies for both the glazing and the mounting method.
- (c) Glazing exposed to wind shall meet the projectile requirements contained in ASCE/SEI 7.
- (d) Glazing on the cab roof shall offer protection from falling objects, if this possibility exists, by being able to support a 50 psf static load.
- (e) Windshield wipers should be installed on the front glazing.

2-2 **STRUCTURAL-MECHANICAL.** There are no industry standards for structural-mechanical components. The following criteria have evolved from successful crane designs administered by Navy Crane Center. Deviation from these criteria for Navy cranes is prohibited, unless approved by Navy Crane Center. Structural members are designed according to structural criteria; the joints between them are designed to comply with the applicable mechanical criteria or other unique requirements. The connections at interfaces of structural and mechanical components are governed by the less stringent criteria of the two. (For example, sheave and equalizer pins shall comply with the mechanical design criteria, but their seats and supports on the boom

may follow the structural design criteria. On either side of the interface, the appropriate design criteria of Section 2-1 or Section 2-3 apply.) Slewing ring (rotate) bearings are standard commercial products; all other structural-mechanical components are custom designed. Additional design criteria for unique structural-mechanical components are given below.

2-2.1 Equalizers.

- (a) Equalizers shall have bronze bushings with flanges or thrust washers in the pivot pin bore or antifriction bearings.
- (b) Bronze bushings shall include provisions for grease lubrication of the bore, normally drilled through the pin.
- (c) Oil impregnated sintered bushings may be used on smaller pins and provisions for grease lubrication may be omitted.

Pin seats in the support structure where there is no relative motion between the surfaces in contact, do not require lubrication.

2-2.2 **Boom Hinges.** Boom hinges shall be arranged to allow the boom to be lowered to its horizontal (maintenance) position and shall be designed to withstand the lateral loads imposed on the boom by side pulls, wind, and rotational acceleration and deceleration of the upper works. Mechanical design criteria apply to the bushings; structural design criteria apply to the hinge pins.

- (a) Lubrication passages shall be arranged to deliver injected grease to the proper locations with the boom at any angle, and to ensure this, the pins may have to be locked against rotation with respect to the boom or the base supports.
- (b) Bushing flanges or separate thrust washers are required between the boom feet and the padeyes.
- (c) The hinge pins shall be forged steel and retained on both ends at the padeyes.
- (d) The pin hardness should be not less than 300 BHN and at least 100 points harder than the bushing material.

2-2.3 Fleeting Sheave Pins

- (a) The ends of the pins are considered structural connections; fleeting sheave pins shall be designed to limit deflection and ensure smooth sliding of the sheaves.
- (b) Fleeting sheave pins shall be plated with nickel and chrome or otherwise permanently treated to provide a low coefficient of friction

and to be resistant to corrosion or made of corrosion resistant steel selected for adequate strength and a low coefficient of friction.

- (c) Lubrication channels are not permitted through the pin and passages shall be designed in the sheave hub and bushing.
- (d) The maximum bearing pressure shall be limited to 1000 psi on the projected area.

2-2.4 Center Steadiments. The bushing and each center steadiment section shall be sized assuming all loads are applied to the steadiment assembly, with no consideration of any mitigating effects of friction on the roller path rollers.

- (a) The upper and lower tubular sections of the center steadiment and their bushings shall be designed for radial and transverse loads due to the rotate drive gear forces, wind, acceleration, and list and trim of the barge for floating cranes.
- (b) The bushing shall be sized to limit the maximum bearing pressure to 1000 psi on the projected area and its ends should be slightly relieved (over 10 percent to 20 percent of its length) to avoid excessive edge loading due to angular misalignment under load.

2-2.4.1 King Pins.

- (a) The king pin bushing is subjected to only nominal loads and has no particular design requirements, other than providing grease lubrication.
- (b) The king pin and its nuts, bushings, thrust washers, and trunnion, shall be sized to comply with the mechanical design requirements at 150 percent of rated hook load at maximum radius. For cranes with variable rating, 150 percent of the maximum operating moment shall be applied.

2-2.4.1.1 Trunnion Mounting.

- (a) Trunnion mounting of the king pin is recommended, but is mandatory only when specified.
- (b) The entire trunnion assembly and its mounting fasteners shall be sized to comply with the mechanical design requirements described in Paragraph 2-2.4.1(b).
- (c) Both ends of the horizontal pin shall be secured with keeper bars.

2-2.4.1.2 Locking Nuts.

- (a) To prevent separation of the upper works from the portal base or tub in case of unintentional overload on the load hooks, the lower end of the king pin shall be threaded for a locking nut.
- (b) In normal service, within the crane's entire operating range, the gap above the locking nut should never close to allow the locking nut to contact the lower center steadiment section.
- (c) The locking nut shall have provisions for securing it against rotation and the gap dimension under a particular load condition shall be recorded.
- (d) The threads shall be sized to comply with the mechanical design requirements described in paragraph 2-2.4.1(b).

2-2.5

Roller Paths.

- (a) Upper and lower roller paths shall be mounted on the supporting structure (in the form of circular or octagonal girders) with intermediate circular steel shim plates for continuous support of the roller path segments.
- (b) The shim plates should be wider than the roller path segment flanges and continuously welded to the supporting structure. The shim plates are intended to serve as surfaces for machining to obtain a level mounting surface for the roller path segments.
- (c) The machined mounting surface shall be level within 1/32 inch (plus or minus) in 12 linear feet.
- (d) The entire supporting structure arrangement shall be of high and uniform rigidity.
- (e) Roller path segments, either in the form of bent rail or machined castings, shall be secured against rotation or shifting in any direction with welded rail clips, welded studs, or through bolts.
- (f) Rail clips should be standard commercial items and should be welded directly to the shim plates in accordance with the manufacturer's instructions.
- (g) The welded studs shall be installed on the supporting structure (through enlarged holes or gaps in the shim plates) per the applicable criteria of AWS D1.1.
- (h) Fastener nuts shall be torqued or (studs tensioned) to the values given in AWS D1.1. Through bolts shall be installed in accordance with the AISC 360.

- (i) When the roller path segments are cast, they may be embedded in an epoxy resin which is poured between the roller path segments and the support structure. The selected epoxy resin shall be poured (installed) in accordance with all recommendations of its manufacturer.
- (j) The width of the roller path segment base and the compressive strength/creep characteristics of the epoxy resin shall be matched, considering maximum roller loads and tension in the mounting studs or bolts.
- (k) The studs and bolts should be tensioned according to the epoxy resin manufacturer's recommendations; the epoxy resin possesses substantial bonding strength but does not have the compressive strength of steel.
- (l) The number of lower roller path segments should be limited to 12 to 18, and the upper segments should be of different length to avoid simultaneous alignment of all upper and lower joints during rotation.
- (m) Cast segments should be alloy steel hardened to a minimum of 225 BHN and their joint faces should be angled from the radial direction.
- (n) Bent rail segments should be of standard commercial rail sections connected with standard railroad type of joint splice hardware. The bent rail roller path flanges shall be held tightly against the support structure because they have a tendency to warp out of the horizontal plane.

2-2.6 **Rollers.** Rollers shall be sized for the maximum load that may be applied to any roller within the rated operating range of the crane. The maximum roller load is calculated by the method described below. The diameters of rollers with straight cylindrical treads shall be uniform within close tolerances to ensure proper load sharing among the rollers. Tapered rollers shall be machined with tight tolerances on the taper to ensure full contact with the roller path running surfaces, and other tolerances adequate to provide the required adjustment range in the roller cage pockets. Tapered rollers shall be equipped with thrust washers designed to carry the outward radial forces imposed on them. Rollers are required to turn on grease lubricated bushings, and tapered roller thrust washers are required to have independent grease lubrication.

2-2.6.1 **Maximum Roller Load.** In determining the maximum roller load, it is assumed that the resultant of all loads from the upper works is applied to the centroids of the front (boom) or rear (counterweight) quadrants of rollers (which fall at 0.90 of the roller path radius). The loads in each quadrant are divided equally among the rollers in that quadrant. Both the front and rear quadrant roller loads shall be calculated. The load cases for straight line rated cranes are:

- (a) Rated load on the main hoist load hook at maximum radius;
- (b) No load on any hoist load hook and the boom at minimum radius.

For variably rated cranes, other load cases shall also be analyzed to determine the highest roller load of either quadrant within the full operating range of the crane.

2-2.6.2 Minimum Roller Diameter. Once the maximum roller load is determined, the minimum roller diameter is calculated using the following formula:

Equation 2-1 Minimum Roller Diameter

$$D = MRL / (K * W)$$

Where,

D = roller tread diameter – (in inches);

MRL = maximum load (in pounds) that is imposed on the roller;

K = sizing factor (1200 for bent rail; 1440 for cast alloy steel);

W = effective width (in inches) of the running surface which is the width of the rail head top minus the corner radii, or the flat machined surface between the corner chamfers – (in inches).

2-2.7 Slewing Ring (Rotate) Bearings. (Applicability includes commercial components)

- (a) Three row roller slewing ring bearings shall be specified for all new cranes unless the loadings are too large for bearings in current manufacture.
- (b) Each row of rollers shall have a static capacity of at least 125 percent of the maximum imposed load.
- (c) The L-10 life (dynamic capacity) of each row of rollers shall be at least 10,000 hours with a representative (average) load of 85 percent of the maximum load condition.
- (d) Split bearing races shall have unthreaded mounting holes.
- (e) The slewing ring bearing and mounting fasteners shall comply with the ultimate strength design criteria in American Petroleum Institute (API) Specification 2C.

2-2.7.1 Slewing Ring Bearing Ring Gears

- (a) The ring gear shall be AGMA, 2015 A5 or better.

- (b) The ring gear teeth shall be machined in the one piece bearing race.
- (c) The ring gear bending strength shall be based on at least 125 percent of the maximum load imposed by the rotate drive or swing lock.
- (d) The rotate drive installation shall include provisions for accurate adjustment of the gear tooth mesh.
- (e) The rotate gear pinion shall have crowned teeth.

2-2.7.2 **Slewing Ring Bearing Mounting.**

- (a) The bearing shall be mounted in accordance with the manufacturer's requirements.
- (b) The machining tolerances of the mounting surfaces, circumferential waviness and radial tilt, shall be within the limits prescribed by the bearing manufacturer.
- (c) Shimming or grouting of the mounting surfaces is prohibited.
- (d) The surface finish roughness height ratings should be between 125 and 250 micro-inches or better if recommended by the bearing OEM.
- (e) The bearing manufacturers mark the geared bearing ring to indicate the location of maximum radial run-out of the gear pitch diameter. This location is used for setting minimum backlash between the pinions and mating ring gear.
- (f) Each ring is also marked with the location of the hardness gap (soft spot) of its raceway surface. The lower ring is positioned with its hardness gap (soft spot) in the location that is expected to be subjected to the lowest loads and the upper ring with the soft spot 90 degrees from the boom-counterweight axis.
- (g) The method used to check the bearings internal clearance and allowable internal clearance shall be provided to the activity. This method, and allowable internal clearance shall be developed by the crane manufacturer in consultation with the bearing manufacturer. The bearings initial internal clearance should be determined before crane acceptance.
- (h) If available, lubrication sampling ports should be provided on the slewing ring bearing.

2-2.7.3 **Slewing Ring Bearing Mounting Fasteners.**

- (a) Bolts and other fasteners shall be sized and tensioned to the stress level specified by the bearing manufacturer, and shall meet API 2C criteria.
- (b) Slewing ring bearing mounting fasteners shall be installed employing a direct tensioning method.
- (c) The fasteners should be equivalent to ASTM A490 bolts or SAE J429 Grade 8 threaded fasteners. Nuts and washers shall be of comparable strength.
- (d) Studs or bolts may be used in smooth (unthreaded) mounting holes.
- (e) Studs shall be used for threaded mounting holes. The mounting hold thread length is determined by the bearing manufacturer and is adequate for the specified fasteners.
- (f) If a non-standard tensioner or other tooling is required to tighten the mounting fasteners, the tooling and instructions should be provided when the crane is delivered.

2-2.8 **Maximum Wheel Load (Portal Cranes).**

- (a) Portal crane wheels shall be designed with a 4-foot spacing (this corresponds to most Navy portal crane rail system allowable wheel loading designs). The maximum wheel loads of the crane shall be reduced proportionally for closer wheel spacing, but they may not be increased for wider spacing. If the rail system allows for different wheel spacing, the acquisition specification will note the allowance.
- (b) The maximum wheel loads calculated by the beaming method are taken as the loads that may not exceed the allowable loads at the assumed spacing for which the rail system was designed. The beaming method is more fully described in Appendix B.

2-2.9 **Travel Truck Systems (Portal and Container Cranes).**

- (a) The equalizers, gudgeons, gudgeon pins, float pins, and travel trucks are designed according to the structural design requirements for the following load combinations:
 - 1. Dead load plus main hoist rated load - both multiplied by an impact factor of 1.25, 40 mph wind, acceleration forces due to rotate and travel motion, and spreading or squeezing forces.

The travel truck float and wheel positions are taken in their most adverse inward or outward locations. The upper works and boom are positioned to produce the maximum corner load. The maximum stresses are limited to 85 percent of AISC 360 allowable values.

2. Dead load and non-operating wind load – from the front, rear, or side – with the boom at the specified radius. The upper works are positioned with the boom in the specified direction. The maximum allowable stresses are limited to 133 percent of AISC 360 allowable values.
 3. For fatigue analyses, the maximum allowable stress range is limited to 100 percent of the AISC 360 allowable values for Condition 2 (that is 100,000 to 500,000 cycles). The larger of the following two stress ranges is to be used:
 - i. Dead load with the boom at minimum operating radius and with no hook load. The stress range is defined as the algebraic difference between the stresses due to: (a) the counterweight positioned to produce the maximum corner load, and (b) the boom positioned to produce the minimum corner load.
 - ii. The stress range defined in paragraph 2-1.6.2(c)(1 (iii), for the main hoist only. The upper works and boom are positioned to produce the maximum corner load.
- (b) The sizing of gudgeons, gudgeon pins, and float pins is determined by the associated bushing design criteria.
 - (c) The sizing of these components is governed by the mechanical design criteria of the mating bushings, thrust washers, and thrust bearings.
 - (d) Wheel axle bearing seats shall be designed so that wheel/axle bearing assembly can be removed with no more that 3 inches of jacking.
 - (e) Equalizers shall have built-in jacking points to support the crane when travel trucks are removed.

2-2.10

Travel Truck Float (Portal and Container Cranes).

- (a) Installed crane rail systems consider the detrimental effects described in Appendix B and provide partial compensation by reducing the rail gauge in the curves. Nonetheless, such reduction cannot fit different travel truck configurations and a float is always required.

- (b) The typical portal crane designs have from 1.0 to 3.0 inches of float to either side of each travel truck. The gauge of the main gudgeons should be selected so the amount of float inward and outward is approximately equal.
- (c) The maximum available float and the maximum travel wheel flange-to-rail clearance shall be included in the design of the system and the portal base.
- (d) The calculation of required float is a complex process that shall be performed or approved by Navy Crane Center for all new crane designs.
- (e) As a practical matter, the amount of float on existing cranes on a crane rail system is a logical point of reference in establishing float requirements.

2-2.11 **Float Pin/Bushing Assemblies (Portal and Container Cranes).** The design details of float pin installations described in this handbook have proven to be successful and shall be followed for new crane designs unless deviation is approved by the Navy Crane Center.

2-2.11.1 **Float Pins.**

- (a) The gudgeon pins of the travel trucks that operate on curved tracks, in addition to accommodating rocker motion, shall also provide for the lateral sliding (float) of the travel truck.
- (b) The required amount of float is a function of the rail gauge, rail radius of curvature, and the portal base proportions; it shall be calculated for each specific installation.
- (c) Transition between travel on curves and straight track changes the effective rail gauge and causes the travel trucks to float and impose lateral squeezing or spreading forces on the portal base and torsion on the equalizers. The magnitude of these forces is the product of the wheel loads and the friction between the float pins and their bushings. Figure 2-1 shows a typical design used on older cranes, and figures 2-2 and 2-3 show those preferred on newer cranes.
- (d) The sizing, material properties, and lubrication provisions for these components are prescribed in detail in Appendix B. These design requirements should be followed to avoid binding at the float pin and the resulting heavy rail head/wheel flange wear and cracked welds in the portal base.

- (e) Float pins should be machined from solid steel with a hardness of at least 300 BHN and with a 63 micro-inch (or smoother) surface finish on the diameter.
- (f) Particular care shall be taken to avoid any machine lead on the sliding surface.
- (g) Other float pin and gudgeon assembly configurations and materials may be considered only with approval of Navy Crane Center.

2-2.11.2 **Float Bushings.**

- (a) Float bushings shall be sized to limit the bearing pressure in the bore (base on the net projected area) to a maximum of 1500 psi.
- (b) Each bushing shall have two independent grease groove patterns – one for the loaded surface, and one for the unloaded surface. (The area of the grease grooves, excluding edge chamfers or radii, in the center quadrant of the loaded surface is subtracted from the total projected area to obtain the net projected area).
- (c) Grooves on the loaded surface shall have sufficient area to lift the float pin and lubricate the adjacent surface with grease under pressure of 8000 psi with no load on the hooks and the crane rotated for minimum corner load.
- (d) Grooves on the unloaded surface are intended only to fill the clearance space with grease to preclude infiltration of water.
- (e) Float bushing material shall be a high-leaded tin bronze, Copper Alloy UNS C93700, with a bore surface finish of 63 micro-inches or smoother.
- (f) Thrust washers should be of the same material as the bushings

2-2.12 **Gudgeon Assemblies (Portal and Container Cranes).**

- (a) Use of thrust washers for supporting vertical loads is not recommended for new truck system gudgeon designs. Existing Navy portal crane truck systems equipped with these thrust washers have encountered undesirable stick-slip conditions. Portal base construction of the older cranes has inherent flexibility that allows them to deform sufficiently to maintain wheel contact on rails with some unevenness.
- (b) Because the all-welded portal base construction of the newer cranes is too rigid to compensate for rail irregularities, their gudgeons in the upper level of equalizers shall be free to slide

(drop down) in their bushings to allow the wheels of an unloaded corner to maintain contact with the rails.

- (c) When thrust bearings are used, the bearing installation shall include provisions to maintain the races and the rolling elements in contact during lift-off conditions.

Figure 2-1 Float Pin

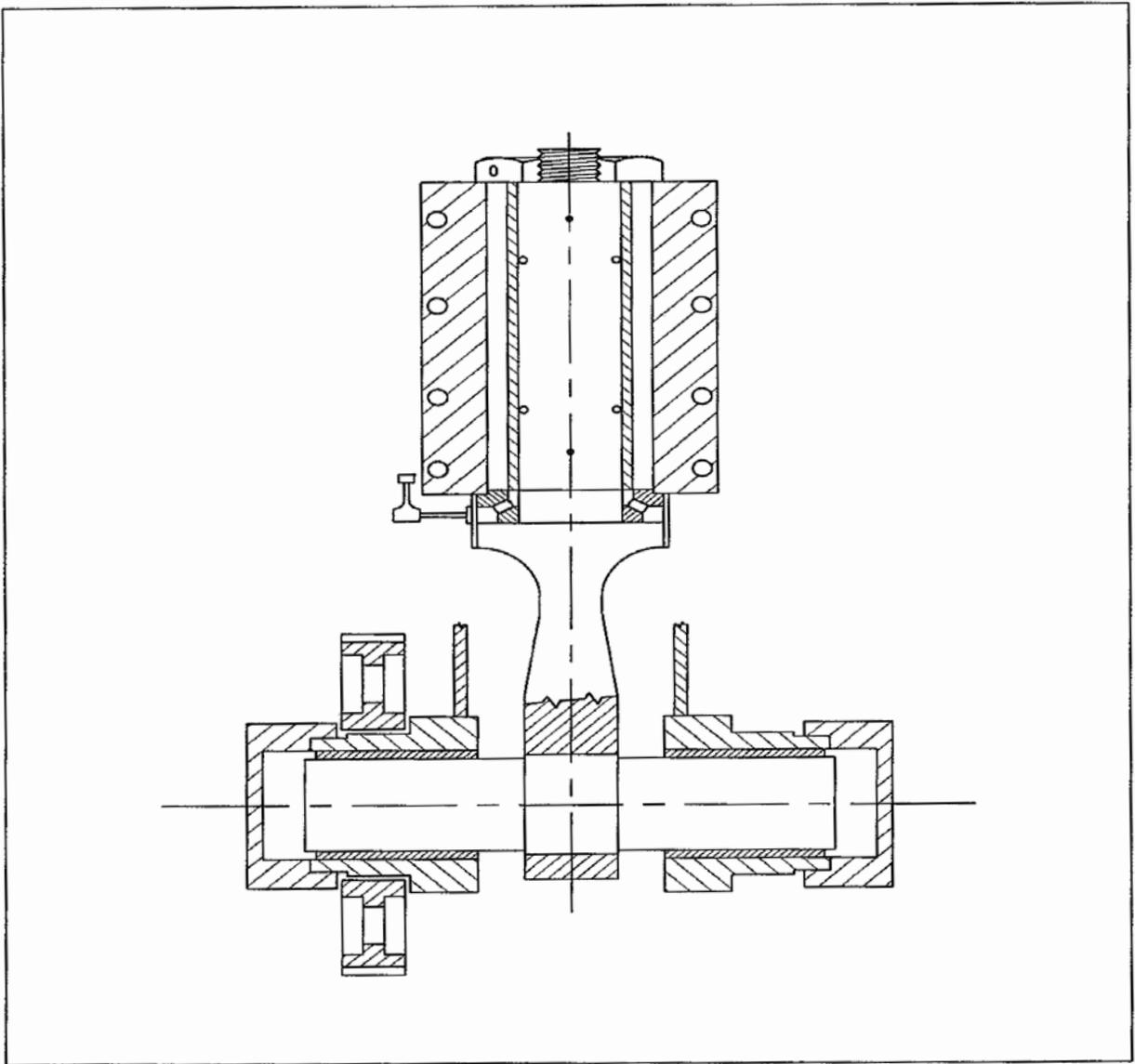


Figure 2-2 Float Pin

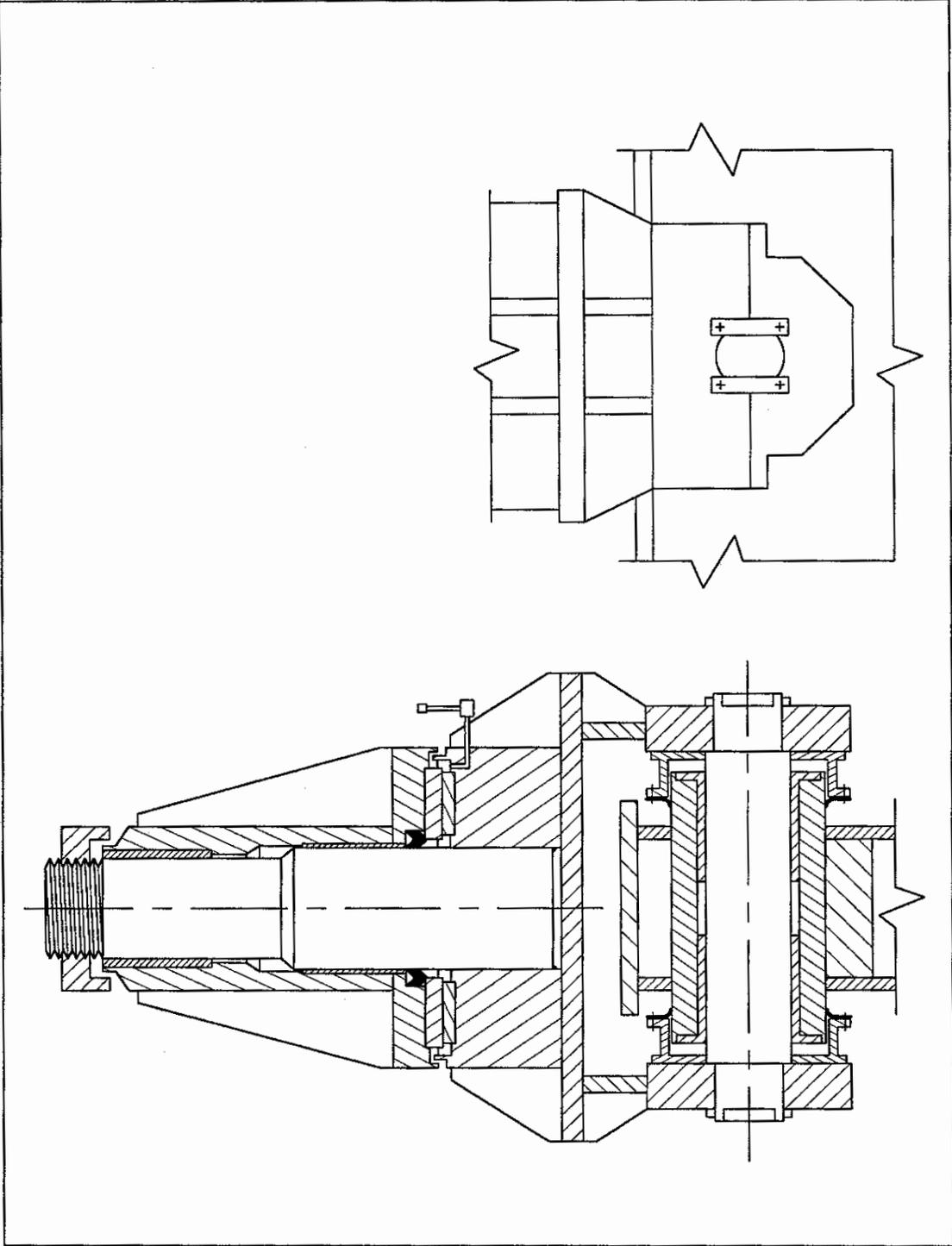
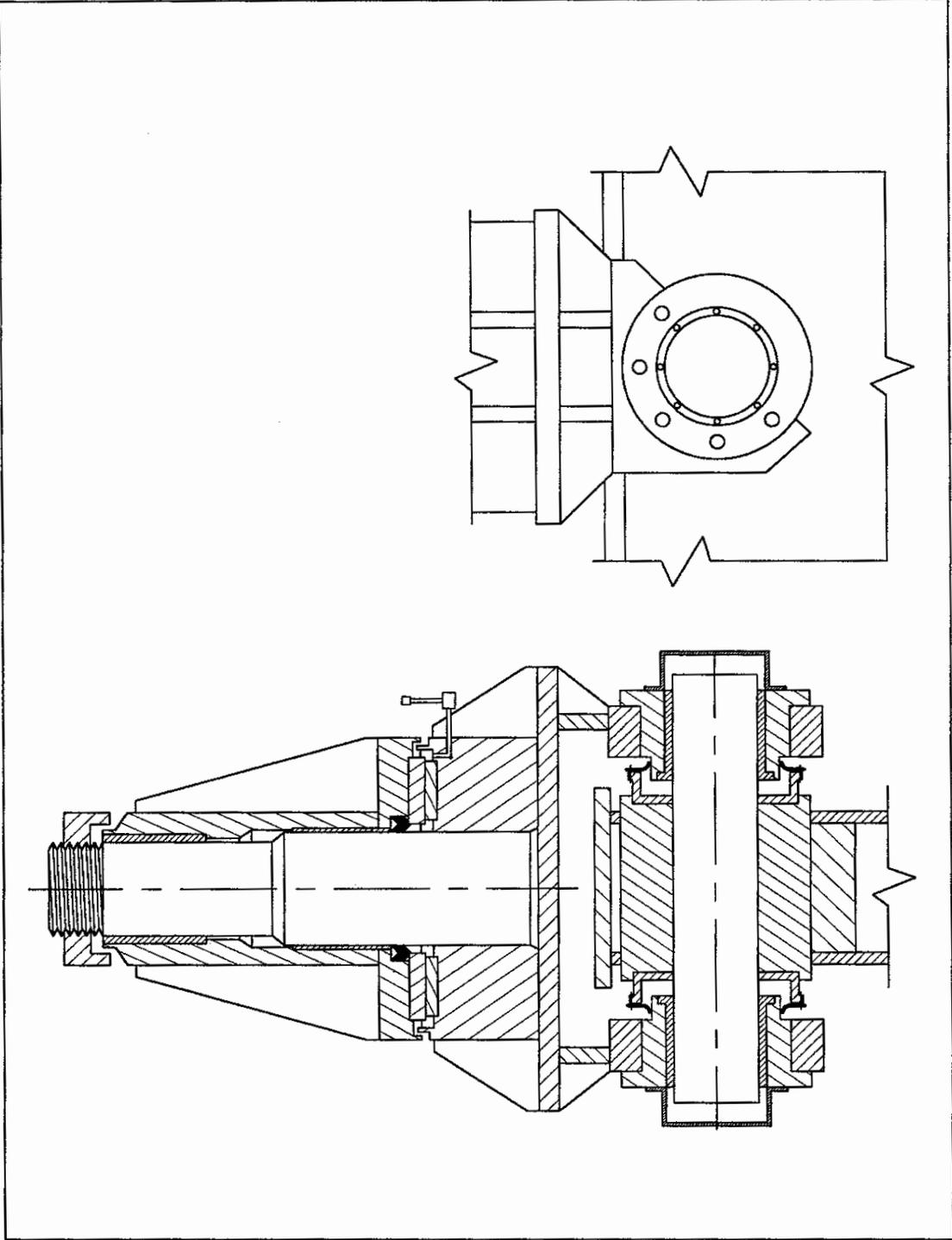


Figure 2-3 Float Pin



2-2.12.1 **Rocker Pins.** Cranes that travel on straight tracks do not require gudgeons. The rocker motion is provided in the form of rocker pins and reinforced extensions of the webs or saddles, either upward or downward, at the pivot points.

2-2.13 **Gudgeon Thrust Washers and Thrust Bearings (Portal and Container Cranes).**

- (a) The design load for these components assumes only the direct vertical loads. (The effects of moments and horizontal loads are assumed to be taken up by the pairs of bushings on individual gudgeons.)
- (b) The governing design load for each thrust washer or thrust bearing is determined by the maximum load obtained from paragraph 2-2.8.

2-2.13.1 **Gudgeon Thrust Washers.**

- (a) Gudgeon thrust washers shall be submerged in an oil bath to ensure an oil film on the rubbing surfaces with minimal relative motion.
- (b) The maximum bearing pressure is limited to 2000 psi, based on the net face area (face area minus the area of the oil grooves).
- (c) The recommended oil groove pattern is a set of three or four intersecting circular grooves.
- (d) The thrust washers should be flat and at least 3/4 inch thick.
- (e) The oil grooves should be 1/4 inch wide by 1/8 inch deep, and without sharp edges.
- (f) The mounting of the thrust washers should be by means of countersunk screws, secured against loosening.
- (g) The thrust washer rubbing surface may separate from its steel contact surface during lift-off conditions. The recommended material for thrust washers is high-leaded bronze, conforming to Copper Alloy UNS C93200.
- (h) Thrust washers of non-metallic materials may be used only when approved by Navy Crane Center. Compared to copper alloys (bronzes), these materials have lower allowable bearing pressures and lower friction coefficients, and usually require no lubrication.

- (i) Thrust washers which serve only to separate adjacent surfaces of equalizers and gudgeon assemblies (in the absence of bushing flanges) may be of any high-leaded bronze.
- (j) Maximum bearing pressure due only to maximum lateral load obtained from paragraph 2-2.8 is limited to 50 percent of the material yield strength.
- (k) The difference between the inside and outside diameters shall be at least 6.0 times the wall thickness of the adjacent bushing.
- (l) The minimum thickness of these thrust washers should be equal to the wall thickness of the adjacent bushing.
- (m) These thrust washers are free to spin and do not require any lubrication.

2-2.13.2 **Gudgeon Thrust Bearings.**

- (a) Gudgeon thrust bearings shall be of either the spherical roller type or three-row roller type.
- (b) The installation of spherical roller type thrust bearings shall maintain the races in contact with the rollers during lift-off conditions; any separation may take place only at the seating surfaces of the races. The three-row roller type bearings consist of three independent rows of rollers specifically designed for thrust loads, overturning moments, and radial loads.
- (c) Bearing selections shall be made on the basis of their static capacities.
- (d) The bearing manufacturer's mounting and installation criteria shall be followed. Manufacturers of the three-row roller type bearings specify the required sizes and grades of mounting fasteners.
- (e) For tapped hole connections, the tapped holes shall be made in the bearing rings.
- (f) Thrust bearings shall either be submerged in an oil bath or be grease lubricated.
- (g) Rolling element bearings are not ideally suited for travel truck swiveling because of the limited amount of rotation and the resulting tendency for brinelling at the roller contact points on the races. However, their low resistance to rotation reduces the load and wear on the travel wheel flanges. For those reasons, rolling element bearings are common in such applications, but they shall

be selected conservatively and shall include any additional design factors that may be recommended by their manufacturer for this application.

2-2.14 **Gudgeon and Gudgeon Pin Bushings (Portal and Container Cranes).**

- (a) Bushings are required for the gudgeons and are recommended for the gudgeon pins.
- (b) These bushings, designed as paired sets, are sized for the highest combination of all horizontal loads and reactions due to the load combinations of paragraph 2-1.6.2 (c).2.
- (c) The maximum bearing pressures are based on the net projected areas.
- (d) The wall thickness shall be at least 1/6 of the finished bore but need not exceed 1.00 inch.
- (e) The grease grooves shall be a minimum of 1/8 inch deep, 1/4 inch wide, and terminate 3/8 inch from the end of the bushing.
- (f) The edges of the grease groove shall be rounded to 0.005 to 0.015 inch radius. (The edge radius may be ignored in calculating the net projected area.)
- (g) The bronze castings shall comply with ASTM B148, B271, B505, or B584, and the casting process shall ensure a homogeneous distribution of the alloy elements.
- (h) For bushings on the gudgeons (vertical axis), maximum bearing pressure is limited to 10 percent of the bushing alloy yield strength. The recommended material for these bushings is heat treated aluminum bronze, conforming to Copper Alloy UNS C95400.
- (i) For bushings on the gudgeon pins (horizontal axis), maximum bearing pressure is limited to 20 percent of the bushing alloy yield strength. The recommended material for these bushings is high-leaded tin bronze, conforming to Copper Alloy UNS C93200.
- (j) Gudgeon pins do not require bushings but they shall be grease lubricated at the contact surfaces where the rocker motion takes place.

2-2.15 **Fasteners and Connections.**

- (a) Fasteners in the load path shall be individually sized according to the applicable design criteria.

- (b) Keeper bars on various components, such as pivot pins, rocker pins, boom hinge pins and roller path fixed axles, that are not subjected to any calculable or significant loads shall be secured with at least two fasteners tightened to the mechanical design criteria.
- (c) Fasteners holding caps and retainers over bearings and bushings in most cases are likewise out of any direct load path, and shall be tightened to the mechanical design criteria.
- (d) Fasteners holding roller path rail segments shall conform to structural design criteria.
- (e) Roller path rail segment fastener installation shall conform to the bearing manufacturer requirements when secured to the crane structure or to resin manufacturer requirements when installed in epoxy resin compounds.
- (f) Bushing and thrust washers with grease grooves requiring alignment with grease injection holes shall be fastened to their support structures with threaded fasteners and locked against backing out.

2-2.15.1 **Threaded Fasteners.**

- (a) Threaded fasteners of custom designed components, both internal to the assembly and those interfacing with foundations, shall be designed or selected to meet the mechanical design criteria.
- (b) Threaded fasteners of commercial assemblies, both internal and mounting hardware, should comply with the applicable industry standards.
- (c) SAE J429 Grade 5 fasteners or ASTM A325 bolts of the intended diameter shall be used with appropriate nuts and hardened steel flatwashers for mounting standard commercial components, such as speed reducers, brakes, and pillow blocks, having mounting holes or slots, unless specified otherwise by the manufacturer.
- (d) The holes or slots shall not be enlarged to accept a larger fastener to obtain the design factor required for custom designed assemblies.
- (e) The installation torque, with lubricated threads, should correspond to approximately 67 percent of the fastener yield strength.
- (f) SAE J429 Grade 8 fasteners and ASTM A490 bolts may be substituted for SAE J429 Grade 5 fasteners or ASTM A325 bolts in

mechanical connections. Installation torque of substitute SAE J429 Grade 8 fasteners and ASTM A490 bolts shall correspond to 67 percent of the SAE J429 Grade 5 material yield strength.

- (g) SAE J429 Grade 8 and ASTM A490 fasteners shall be pre-loaded to their full installation torques only when so prescribed by the component manufacturer.
- (h) Custom designed joints and connections shall have fasteners and bolts sized for design factors of 4 and 5 based on material yield and ultimate strengths, respectively.
- (i) Tapped threads shall be analyzed for the required length of engagement.
- (j) Tapped threads should have yield and ultimate strengths equal to or exceeding those of corresponding nuts.

2-2.15.2 **Washers.**

- (a) Threaded connections of built-up assemblies shall have a hardened steel flatwasher under each turned element, either the head or nut.
- (b) Mounting connections with slotted holes in the feet or flanges of housings shall have a thick steel cover plate with a drilled hole to match the fastener diameter and overall dimensions to completely cover the slot.

2-2.15.3 **Shims.**

- (a) Shims, when used, shall be corrosion resistant for all applications and environments – outdoor and indoor.
- (b) Shim stacks should be limited to four shims.
- (c) Commercially available shim kits should be used as they provide a wide assortment of neatly pre-cut shims slotted for standard fastener sizes.
- (d) New equipment shall be installed with a minimum of 0.100 inch shim under each foot.
- (e) Soft foot on new equipment shall be limited to 0.001 inch.

2-2.15.4 **Set Screws.**

- (a) Setscrews shall be used only as locking devices between the threads of mating components (such as load hook and nut),

mounted bearings supporting only the weight of mechanical components (such as squaring shafts), to secure keys, retain disk brake hubs against axial movement, and on secondary non-load bearing assemblies (such as limit switch shafts).

- (b) Setscrews seating on threads shall have a soft non-metallic tip to preclude marring the threads.
- (c) Setscrews should be of the headless type.
- (d) Setscrews fitted into a pocket should have a full-dog or half-dog point
- (e) Setscrews bearing on a flat should have a cup point.

2-2.15.5 **Retaining (Snap) Rings.** On custom designed assemblies, retaining rings shall only be used in locations with low shaft stresses and minimal axial forces.

2-2.15.6 **Cotter Pins.**

- (a) On custom made assemblies, cotter pins shall only be used to lock nuts against loosening or for retention of secondary components which are not in the primary load path.
- (b) When standard commercial items are available both with and without cotter pins, those without cotter pins should be selected.
- (c) Cotter pins on outdoor installations shall be corrosion resistant.

2-2.16 **Shear Bars and Dowel Pins.**

- (a) Foot (base) mounted components and housings that are subjected to shear loads which exceed the holding capacity of the mounting fasteners or where maintaining alignment is critical to proper component operation shall use shear bars or dowel pins to maintain their alignment. Dowel pins are preferred for alignment aids while shear bars are preferred for load carrying capacity.
- (b) Welds between the shear bars and the foundation shall be designed and placed in order for the shear bar to maintain contact with the foundation as the weld cools.
- (c) Dowel pins shall be designed and installed in accordance with ASME B18.8.2.

2-2.17 **Bumpers and End Stops. (Applicability includes commercial components)**

- (a) Crane structures or components that come into powered contact with end stops shall have bumpers unless the bumper is mounted on the end stop.
- (b) Bumpers contacting existing end stops shall be designed to not exceed to design forces of the end stop or supporting structure.
- (c) Bumpers shall provide proper clearance between the crane and surrounding structures or other cranes when compressed.
- (d) Bumpers shall be designed to properly mate with existing end stops or other crane bumpers.

2-2.17.1 **Bumpers.**

- (a) Bumpers shall be able to absorb and dissipate the kinetic energy of the crane (s) or crane component(s) traveling at 100 percent rated speed with the power off, per AIST TR No.6. Bridge crane bumpers shall also meet the requirements of CMAA #70 and #74 and ASME B30.2 and B30.17.
- (b) Container cranes and portal cranes (when specified) shall be equipped with spring or hydraulic bumpers on both the travel trucks and trolley.
- (c) Container crane travel truck bumpers should be designed for a deceleration rate of not more than 4.5 feet/second/second when contacted at 100 percent of the rated speed, with the power off. Bumper strokes should be calculated using an efficiency of 0.5 for spring bumpers and 0.8 for hydraulic bumpers.
- (d) Boom bumpers (buffers) on floating cranes, container cranes (mounted on the A-frame or gantry structure), and portal cranes (when used) should be selected to absorb and dissipate the kinetic energy of the boom at its rated speed at the contact position without any damage to the structural or mechanical components of the crane.

2-2.17.2 **End Stops.**

- (a) End stops shall be sized to absorb the maximum kinetic energy and impact force developed by the striking bumper as determined in 2-2.17.1 (a).
- (b) Top running crane bridge end stops should be installed on the runway girders.

- (c) Top running trolley end stops should be installed on the bridge girder.
- (d) Portal, container, and gantry crane end stops should be installed on the rail support structure.
- (e) Under running crane bridge, trolley, and hoist/trolley unit end stops should be bolted to the girder web.
- (f) End stops that engage the wheel shall not be used except for manual powered trolleys.

2-3

MECHANICAL.

- (a) Crane industry standards CMAA #70 and #74 MMA MH27.1, and ASME B30, prescribe mechanical design criteria for various cranes. Some elements of those design criteria are recommendations (“should” statements). However, Navy Crane Center considers them mandatory. Deviation from these criteria is permitted only with the approval of Navy Crane Center. The following requirements are intended to supplement industry standards.
- (b) Design and selection of mechanical drive components are governed by the rated torque of the drive motor; and that of the wire rope drum and supporting components by the drum line pull.
- (c) The generally applied minimum design factors for mechanical components are 4 and 5 based on the material yield and ultimate strengths, respectively.
- (d) Except where stated otherwise, mechanical components that are subjected to momentary peak loads (due to starting, braking, or locked rotor torque) shall be designed to limit the peak stresses to 0.75 of the material yield strength, except that peak compressive stresses shall be limited to 0.90 of the material yield strength.
- (e) Some mechanical components, both custom designed and off-the-shelf, are designed according to unique industry standards and procedures, which in general are followed by Navy Crane Center and are outlined in the following paragraphs.

2-3.1

Hoists.

- (a) The hoist system, either built-up or standard commercial units shall be designed to the specified service or duty class.
- (b) See Section 2-4.1.1 for hoist brake requirements.

- (c) Pneumatic hoists shall stop the load during a loss of air pressure when the controller is returned to the off position.

2-3.1.1 **Built-Up Hoists.**

- (a) A full-flexible or semi-flexible coupling and, if necessary, a floating shaft shall be used in connections between the electric motor and the speed reducer input (high speed) shaft.
- (b) No shafts, including the wire rope drum shaft or speed reducer output shaft, may be mounted in a three (or more) bearing configuration.
- (c) For wire rope drums without ring gears, barrel type couplings or a semi-flexible type coupling of adequate radial and axial load capacities shall be used in connection between the hoist reducer output shaft and the wire rope drum flange.
- (d) A wire rope drum designed with a ring gear shall be engaged with a gear pinion either terminated on the end of the speed reducer output shaft, or mounted independently and driven by the speed reducer via a shaft/coupling connection.
- (e) Luffing (boom) hoists, shall be equipped with a ratchet-and-pawl mechanism on the drum to positively lock the drum against any possible downward motion when engaged. The boom hoist pawl shall be controlled from the operator's cab. The boom hoist pawl operating system shall be designed so that power is not required to maintain the pawl in the engaged or disengaged position.

2-3.1.2 **Commercial Package Hoists. (Applicability includes commercial components)**

- (a) A commercial package hoist is defined as a hoist where the components are mounted via c, d, or p-face flanges as opposed to being separately mounted. Package hoists shall be mass produced by established manufacturers of the crane industry.
- (b) Commercial package hoists and underhung (under running) hoist/trolley units shall be designed and constructed according to ASME HST performance standards.
- (c) Hoist duty service classification shall be H3 or A4 minimum.
- (d) Underhung package hoist/trolley units shall have safety lugs (drop stops) or a functionally equivalent feature on the trolley frame to prevent derailment and limit the drop to no more than one inch in the event of wheel or axle failure.

- (e) Powered trolleys for hoist/trolley underhung units shall be equipped with a brake or non-coasting drive. The trolley frames (or a functionally equivalent feature) shall contact the end stops (no wheel to end stop contact). The trolleys (or end stops) shall be equipped with bumpers.
- (f) Commercial packaged chain hoists shall utilize welded link load chain unless otherwise approved by the Navy Crane Center. A chain stop or dead end connection shall be provided to prevent the load chain from running out of the hoist at its fully extended position.
- (g) Commercial package hoists shall have a hoist overload limiting device that prevents hoisting in excess of the test load.
- (h) Commercial package hoists, with the exception of pneumatic and manual hoists, shall have a minimum of two hoist holding brakes. A mechanical load brake or self-locking worm gear may be utilized in lieu of one of the hoist holding brakes provided it stops and holds 130 percent of the hoist's rated load
- (i) Pneumatic commercial package hoists shall stop the load during a loss of air pressure when the controller is returned to the off position.

2-3.2 **Gears.** (Applicability includes commercial components)

- (a) Gearing shall conform to AGMA 2001 and AGMA 908.
- (b) Gear quality shall be A5 or higher.
- (c) Internal and external gear dimensional tolerances shall conform to AGMA 2000.
- (d) With the exception of package hoists, hoist gearing shall be mounted on shafts supported by two outboard bearings. Three bearing shafts shall not be used.
- (e) Overhung gears are not recommended. If they are utilized, the supporting bearings must be analyzed to ensure the overhung loads will not overload their capacity.

2-3.2.1 **Open Gearing.**

- (a) Open gear teeth shall be spur, double helical or herringbone to preclude axial loads on their supports.

- (b) The open gear horsepower rating shall be greater than the horsepower rating of the driving motor.
- (c) Stress cycle factors, Z_N and Y_N , and reliability factor, K_R , shall be taken as 1.0.
- (d) Open bevel gears shall not be utilized.
- (e) Open pinion teeth of last stage gear sets shall be crowned.
- (f) The bending strength of idler gears driving more than one wheel on travel drives shall be reduced to 70 percent of their normal rating.
- (g) Open gearing shall be protected whenever feasible by a metal cover with spring loaded lids for inspection of the gear teeth, tooth contact at the mesh, and lubrication.

2-3.2.2 Enclosed Gearing (Speed Reducers). (Applicability includes commercial components)

- (a) Speed reducers shall be standard commercial products, and conform to AGMA 6001.
- (b) Back-driving (overhauling) capability of the unit as well as the static and dynamic efficiency shall be considered when selecting speed reducers.
- (c) The minimum speed reducer service factor shall conform to AGMA 6009 and 6010 for load durations of 3 to 10 hours per day, unless operating conditions justify a different load duration.
- (d) Speed reducer housings for hoists, and for rotate drives on portal and floating cranes shall be steel or ductile cast iron. Other speed reducer housings may be gray cast iron or cast aluminum.
- (e) Portal and floating cranes shall use "Dry Dock" service factors.
- (f) Cranes with a CMAA rated service class "D" shall use "Mill Duty" service factors.
- (g) Cranes with CMAA rated service class "C" shall use "Industrial Duty" service factors.
- (h) Keyed connections external to the speed reducer housing shall be parallel square or rectangular keys.

- (i) Spur, helical and bevel speed reducers shall conform to AGMA 6010, if equipped with input and/or output shafts, or AGMA 6009, if equipped for shaft mounting.
- (j) Shaft mounted reducer torque arms shall not be pinned with threaded rod.
- (k) Worm gear speed reducers shall conform to AGMA 6034 if cylindrical (single enveloping) or AGMA 6017 if of the double enveloping (hourglass) type.
- (l) Worm gear type speed reducers should not be used in hoist applications unless specifically approved by Navy Crane Center.
- (m) Epicyclic (planetary) speed reducers shall conform to AGMA 6023.
- (n) The input (high speed) gear set shall be some form of angled gear tooth form – helical (including double helical and herringbone), spiral bevel, or worm. The output (low speed) gear set may be of a straight gear tooth form – spur or plain bevel. This does not apply to commercial package hoists.
- (o) The total gear ratio between a motor and its driven load shall be computed, not on the motor's base or synchronous speed, but on the actual speed produced by the motor when developing the required torque to maintain the desired rated load running speed.

2-3.3 Travel and Rotate Drives. (Applicability includes commercial components)

2-3.3.1 Portal, Container, Outdoor Bridge Crane, and Gantry Travel Drives.

- (a) Rail mounted cranes shall have half of the wheels per travel truck driven.
- (b) Outdoor bridge cranes should have half the total wheels driven in order to provide adequate holding capability against out of service wind loads without providing additional wind tie-downs.

2-3.3.2 Portal and Floating Crane Rotate Drives.

- (a) Each rotate drive shall be designed to operate, without back driving, in maximum operating wind condition with the worst case loading imposed on the drive.
- (b) For floating cranes, the rotate drive shall also advance the upper works against the slope determined from the compound list/trim angle.

- (c) If a shoe brake is used in a rotate drive arrangement that has vertically oriented motor/speed reducer input shafts the shoe brake shall be mounted on a vertical shaft. Vertical shaft mounting shall require modifications to the shoe brake to prevent the linkage from sagging and applying the brake shoes unevenly to the brake wheel.
- (d) The rotate drive installation shall include provisions for accurate adjustment of the gear tooth mesh.

2-3.4 **Shafts and Axles.**

- (a) The location and geometry of the keyseat shall be evaluated for its effect on the fatigue strength of the shaft or axle.
- (b) Each custom designed shaft and axle shall have a comprehensive fatigue analysis per AGMA 6001.
- (c) All gears and travel wheels, with the exception of those in the rotate assembly and carrier yokes, should be pressed on and turn with their shafts or axles.

2-3.4.1 **Selection of Design Factors.**

- (a) The fatigue design factor shall be a minimum of 1.5.
- (b) If the given ultimate strength of the material is the minimum value, then the reliability factor (k_c) of 1.00 shall be used;
- (c) If the given ultimate strength is an average or representative value, then the reliability factor of 0.817 or 0.747 shall be used for reliabilities of 99.0 percent and 99.9 percent, respectively.
- (d) The choice of the level of reliability depends on the criticality of the drive and crane service. A reliability factor of 0.817 is appropriate for most applications.
- (e) The life factor (k_e) shall be 1.0.
- (f) Shafts and axles shall be designed for an infinite fatigue life.
- (g) For analysis, every reversed bending cycle shall be assumed to be at the rated torque.

2-3.5 **Pins.**

- (a) Pins, including trunnions, are non-rotating mechanical members in which the transverse shear stress is a major contributor to the

combined stress. The pins support pivoting or rotating components such as ratchet pawls, spud locks, or sheaves. The loads that are imposed on them are considered to be static for design purposes. The required design factors for the combined stress are 4 on the yield and 5 on the ultimate strength of the material. It is common practice to drill numerous holes through these pins to serve as lubrication passages to the bushings or sheave bearings mounted on them. The loss of strength due to these holes shall be considered in the design of the pins.

- (b) Both ends of gudgeon and equalizer pins shall be locked – this may be in the form of a keeper bar on each end or a head on one end and a keeper bar on the other end.
- (c) The only exception to this practice is to permit one end to be secured with a keeper bar if the other end protrudes by at least half the pin diameter, not including the chamfer.
- (d) Keeper bars shall not be welded to the pins.

2-3.6 Couplings. (Applicability includes commercial components)

- (a) Torque carrying components of couplings shall be steel, with the exception of limit switches, other indicators, and diesel engine to generator couplings.
- (b) Semi-flexible couplings shall be used on floating shafts and shaft arrangements where one shaft has sufficient length such that shaft deflection easily compensates for misalignment and the other shaft does not.
- (c) Full-flexible couplings shall be used on connecting shafts and axles with adjacent bearing supports.
- (d) Rigid couplings are permitted only on long shafts (with distant bearing supports) where shaft deflection easily compensates for any misalignment.
- (e) Conventional shaft couplings are designed to transmit only torque and with the exception of the weight of the shaft, couplings shall not be loaded in the radial direction.
- (f) Disc or diaphragm couplings, chain couplings, and elastomeric couplings may be used with Navy Crane Center approval in non-hoist applications. Gear couplings shall be bolted flange type.
- (g) Spline couplings are acceptable as originally installed and as replacements on c, d, or p-face assemblies.

2-3.6.1 **Proprietary Couplings.** The selection of these couplings and the mounting details shall be made in consultation with their manufacturer.

2-3.7 **Bearings.**

- (a) Rolling element (antifriction) bearings shall be selected on the basis of their published static and dynamic ratings.
- (b) Antifriction bearings shall have both inner and outer races.
- (c) Tapered roller bearings should be used when heavy axial loads are present.
- (d) Grease lubricated bearings (unless designed and selected for permanent lubrication) shall include provisions for the purging of old grease – either past the seal lips or through relief fittings.

2-3.7.1 **Selection of Design Loads and L-10 Lives.**

- (a) New portal, floating and container cranes shall use table 2-4 for bearing life determination criteria.
- (b) For all other cranes CMAA #70, #74, or ASME HST Performance Standards shall be used to determine bearing life criteria, as applicable.

Table 2-4 Bearing Life Determination Criteria

Crane Type	Drive	L-10 Life (Hours)	% Maximum Load
Portal and Floating	Main Hoist, including sheaves and load block	5,000	75
Portal and Floating	Auxiliary hoist, including sheaves and load block	7,000	75
Portal and Floating	Whip hoist, including sheaves and hook assembly	8,000	75
Portal and Floating	Luffing hoist, including sheaves	5,000	75
Portal and Floating	Rotate, excluding the rotate bearing	7,000	85
Portal	Travel, including axles	10,000	85
Container	Hoist, including sheaves	25,000	75
Container	Boom hoist, including sheaves	15,000	75
Container	Trolley, including axles	25,000	75
Container	Travel, including axles	15,000	100
Container	Re-reeving devices	15,000	75

2-3.7.2 **Hook Thrust Bearings.** Hook thrust bearings shall be selected on the basis of the published static rating, which shall be at least 50 percent greater than the hoist rating.

2-3.7.3 **Mounted Bearings.**

- (a) Manufacturers' published ratings for the mounted bearings, with consideration of the load direction and mounting details, shall be followed.
- (b) The housings of pillow block bearings in the hoist drive train shall be made of steel – either as castings or machined from rolled plate as a custom made component. Weldments are prohibited for pillow block housings in these applications.
- (c) The housings or pillow blocks of light duty applications, such as support of squaring shafts, shall be steel or any class of cast iron.

- (d) Piloted flanged cartridge bearing housings that are subjected to significant loads shall be ductile iron or steel castings; those supporting only the weight of mechanical components may be cast iron of any class.

2-3.8 **Bushings.**

- (a) Bushings subjected to rocker (dithering) motion shall have the maximum allowable bearing stress in the bore limited to 20 percent of the material yield strength in compression, based on the projected area.
- (b) Bushings subjected to full rotation and sliding, as those in fleeting sheaves, shall have the maximum bearing stress in the bore further restricted to 1000 psi or the bushing manufacturer's maximum recommended product of bearing stress and rubbing velocity, whichever is less.
- (c) The steel shaft or pin shall be at least 100 BHN points harder than the bushing material.
- (d) Grease grooves shall be cut in the bushing.
- (e) Bushing wall thickness shall be at least 1/16 of the bushing bore.
- (f) Bushings should have integral flanges or separate thrust washers of the same material. The outside diameter of the flange or thrust washer should be sized to provide a low bearing stress with the adjacent structure.
- (g) Bushing flanges and thrust washers which are intended for specific and significant loads shall be designed to the same criteria as the bushings.

2-3.9 **Shaft to Hub Connections.**

- (a) All components that transmit hoist drive or brake torque shall be keyed with the exception of spline connections installed as original equipment on commercial off the shelf items.
- (b) All components that transmit drive or brake torque shall be interference fitted (pressed) onto their shafts or axles.

2-3.9.1 **Keys, Keyseats and Keyways.**

- (a) Keys, keyseats and keyways shall be designed in accordance with ASME B17.1.

- (b) Keys, keyseats and keyways shall be designed based on rated motor torque and momentary peak loads due to starting, normal or emergency braking, or locked rotor torque, as applicable.
- (c) Keys shall be of the parallel type, made from cold-finished low carbon steel commercial keystock or heat-treated alloy steel.
- (d) For the full rated torque of the drive motor, the maximum allowable compressive stresses on the hub keyway, key, and shaft keyseat are $0.33S_y$; and the maximum allowable shear stress on the key is $0.192S_y$; where S_y is the minimum tensile yield strength of the material.
- (e) For momentary peak loads, the maximum allowable compressive stresses on the hub keyway, key, and shaft keyseat are $0.900S_y$; and the maximum allowable shear stress on the key is $0.520S_y$; where S_y is the minimum tensile yield strength of the material.
- (f) Keys shall be chamfered to clear keyseat and keyway radii.
- (g) Chamfers, fillets, and end radii shall be subtracted from the projected areas when calculating stress.
- (h) The keys shall be designed and installed to prevent shifting out of position.

2-3.9.1.1 **Key Fits.**

- (a) Keys in reversing torque applications shall have a metal-to-metal fit to the keyseat and keyway.
- (b) Single keys shall be fitted in their keyseats and keyways to ASME B17.1 Class 2 requirements.
- (c) Double keys may be fitted to ASME B17.1 Class 1 requirements.

2-3.9.2 **Keyless Connections.**

- (a) Travel and rotate drive speed reducers may use keyless connections.
- (b) Keyless connections, if used, shall be through either a locking device or an interference fit.
- (c) Keyless connection interference fits shall transmit peak load torque and not less than 200 percent rated motor torque.

- (d) The manufacturer's procedure shall be followed to size hub dimensions and material for keyless connection locking devices.

2-3.9.3 **Cylindrical Fits.**

- (a) Fitted cylindrical parts shall conform to ASME B4.1.
- (b) Consideration shall be given to the ease of future disassembly when detailing press fitted assemblies.
- (c) Interference fits shall conform to the tolerance ranges for Class FN2 medium drive fits unless material, hub-to-bore diameter ratio, press sliding distance, or other design condition justifies another fit.
- (d) For assemblies such as wire rope drums with non-stepped shafts, where the shaft shall pass through the length of the drum, Class LC1 locational clearance fits may be used.
- (e) Installation fits of standard commercial components, such as bearings and seals, should follow the manufacturers' recommendations.

2-3.10 **Sheaves.**

- (a) Sheaves shall be forged steel.
- (b) Rims of running sheaves shall be heat treated to a minimum hardness of 320 BHN in the groove.
- (c) Running sheave pitch diameters for 6x36 class of wire rope construction shall be at least 30 times the wire rope diameter for portal, floating and container cranes. Running sheave pitch diameters for rotation-resistant wire ropes shall be at least 40 times the wire rope diameter.
- (d) On portal and floating cranes, equalizer sheave pitch diameters for all classes of wire ropes shall be the same as the running rope sheave diameter.
- (e) For all other cranes, equalizer sheave pitch diameters shall not be less than $\frac{1}{2}$ of the diameter of the running sheaves, and also shall not be less than 12 times the rope diameter when using 6x36 class rope, or 15 times the rope diameter for all other classes of rope.
- (f) The groove depth shall be at least 1.15 times the wire rope diameter, the groove included (throat) angle 30 to 40 degrees, and the groove diameter shall be in accordance with the Wire Rope Users Manual.

2-3.11 **Travel Wheels. (Applicability includes commercial components)**

- (a) Top running wheels shall be double flanged.
- (b) Wheels that are required to cross rail head gaps at frogs or track switches by transferring their load from the tread to the flanges shall have their flanges hardened and designed to carry the maximum calculated imposed load on the wheel.
- (c) Drive wheels installed to rotating axles without keys shall be machined to have the wheel/axle interference fit in the FN2 to FN3 fit range.
- (d) Paired drive wheels with cylindrical (straight) treads, such as trolley wheels and wheels driven by an idler gear in portal crane travel trucks, shall have their tread diameters matched to 0.001 inch per inch of diameter but not to exceed 0.010 inch.
- (e) Tapered tread wheels on bridge travel drives shall be either 1:20 or 1:25 taper and shall be installed with the large diameter toward the center of the bridge span.
- (f) Wheels shall not be manufactured from plate steel.
- (g) The tread width is governed by the size of the rail head, with total clearance of 1/4 to 1 1/2 inches depending on the wheel size and crane component.

2-3.11.1 **Bridge, Gantry, Semi-Gantry and Trolley Wheels.**

- (a) Bridge, gantry, semi-gantry and trolley wheels that run on top of runway rails shall be rolled-to-shape or roll-forged to provide properties in conformance with ASTM A504 and shall be rim toughened to not less than 320 BHN.
- (b) Underhung package hoist/trolley unit wheels shall be the manufacturer's standard (except as specified below) and shall be suitable for the specified service.
- (c) Hollow stamped wheels and gray cast iron wheels shall not be used.
- (d) Wheels that operate on patented track shall be hardened to a minimum of 375 BHN.

2-3.11.2 **Portal and Container Crane Wheels.**

- (a) For general applications, where the wheels run on straight rails uninterrupted by frogs or cross-overs, the wheels shall be rolled-to-shape or roll-forged to provide properties in conformance with ASTM A504 and shall be rim toughened to not less than 320 BHN.
- (b) The hardened surface for wheels shall extend across the wheel tread and the inner flanges faces.
- (c) For wheels where the flanges carry the wheel load, the hardened surface shall extend to the outer faces of the flanges.
- (d) In applications where increased service life or resistance to abrasion is required, wheels shall be heat treated and case hardened to a minimum of 48 Rockwell C Hardness (Rc).
- (e) Case hardened wheels shall be manufactured from fine grain, fully killed, vacuum degassed forged or alloy steel.
- (f) The hydrogen content of the forged steel material shall be tested in the ingot mold and shall not exceed 2.0 PPM. The forgings shall be fully normalized prior to hardening to ensure a grain size of ASTM number 5 or finer throughout the forging. The steel forgings shall conform to ASTM A668.
- (g) A hardness gradient shall be specified to provide a smooth transition without a drastic or abrupt change in hardness from the specified surface hardness (at the tread and flange surfaces) to the core material properties to sustain sub-surface shear stresses at maximum wheel load.
- (h) Material in the web and hub area of the wheels shall be core material hardness.
- (i) A sample test wheel (manufactured by the process which shall be used to make all the wheels) may be required to be sectioned and tested to demonstrate the degree and depth of hardening.
- (j) The wheels shall be sized for the maximum wheel load. The minimum wheel tread diameter shall be determined using the following equation:

Equation 2-2 Maximum Wheel Load and Minimum Wheel Tread Diameter

$$MWL = K \cdot W \cdot D$$

Where,

MWL = maximum calculated imposed load on the wheel in pounds

K = sizing factor, dimensionless, usually 1,500 for rail head hardness of 320 BHN. For other rail head hardnesses, the maximum value of the K factor should be determined as follows:

$$K = 2.5(BHN \text{ of wheel tread} + BHN \text{ of rail head})$$

W = effective width of rail head which is the width of the rail head top minus the corner radii in inches

D = minimum wheel tread diameter in inches

- (k) Wheel profiles shall be determined by the rail system; however, the wheel treads (distances between interior faces of flanges) shall be at least 1.0 inch wider than the rail head.
- (l) Flange thickness and flange height shall match the rail system frogs and switches.
- (m) The included angle between the flanges shall be 2.0 to 5.0 degrees wider than the angle of the rail head sides, and the fillet radius with the tread shall be 0.030 to 0.060 inch less than the corner radii at the top of the rail head.

2-3.11.3 Other Wheels.

- (a) Under running wheels operating on rolled shape beams or patented track shall be cast or forged steel, or ductile or malleable cast iron.
- (b) The equation determining the K factor applies to various non-standard wheel materials and running surfaces, such as bronze wheels or cast rail segments of roller paths, among others. The value of K may be raised by up to 200 for cranes in light service and should be lowered by up to 200 for severe service.
- (c) Idler wheels of roller path assemblies are relatively small and are usually machined from steel bar stock are closely spaced and are intended to share the load imposed on either quadrant of the roller path. These wheel tread diameters shall be held to 0.001 inch per inch of diameter.

2-3.12 Wire Rope Drums. The drum line pull, calculated by the formulas shown in paragraph 2-3.13.1, is the governing design load for the drum and all other components of the reeving system.

- (a) The wire rope shall spool onto a single layer, grooved drum unless space requirements require multi-layer spooling.
- (b) Multi-layer arrangements shall be approved by the Navy Crane Center.
- (c) Drums with multiple layer spooling shall employ Lebus lagging.
- (d) The drum groove radius shall be within minimum and maximum range recommended by the Wire Rope Users Manual.
- (e) One empty groove for each rope shall remain on the drum with the hook is in the highest position.
- (f) For portal, floating and container cranes, the wire rope drum pitch diameter shall be a minimum of 30 times the wire rope diameter for non-rotation resistant rope, and 40 times the wire rope diameter for rotation resistant rope.
- (g) For portal, floating and container cranes, the wire rope drum groove pitch shall be a minimum of 1.125 times and a depth of 0.375 times the nominal wire rope diameter.
- (h) There shall be a minimum of two dead wraps at each anchorage remaining on the drum at the lowest working condition for grooved drums.
- (i) The drum end flanges should extend a minimum of one rope diameter above the top layer of wire rope; 2 rope diameters for multi-layer drums.
- (j) Wire rope drums shall be constructed of steel.
- (k) On welded drums, the longitudinal welds of drum barrels shall be full depth penetration welds.

2-3.12.1 **Anchor Points.**

- (a) The wire rope dead ends shall be anchored on the drum barrel by clamping or by inserting end fittings into reinforced pockets.
- (b) Drum end anchoring by means of wedge sockets shall not be used except for package hoists and mobile cranes.

2-3.13 **Wire Ropes.** (Applicability includes commercial components and paragraph 1-3.3 cranes)

- (a) Hoist wire ropes shall be improved, extra-improved, or extra-extra-improved plow steel, bright (uncoated, non-galvanized), pre-formed, regular lay, with an independent wire rope core. The classification shall be appropriate for the usage.
- (b) Wire rope shall comply with Federal Specification RR-W-410, ASTM A1023/A, or ISO 4309 as appropriate.

2-3.13.1 **Selection.** Wire rope shall be selected on the basis of the drum line pull (which occurs at the drum during hoisting) calculated as described below to account for the friction and bending losses at the sheaves or based on the applicable document:

- (a) Wire rope selection for top running bridge cranes, and package hoists shall be in accordance with CMAA # 70, and ASME B30.16 respectively.
- (b) Wire rope selection for mobile and articulating boom cranes shall be in accordance with ASME B30.5 and B30.22 respectively.
- (c) For all other crane designs, the following calculations shall be used:

Equation 2-3 Drum Line Pull

$$P = \frac{W}{NE}$$

Where;

P = drum line pull (in pounds);

W = total weight supported (in pounds);

N = number of parts of line supporting the load; and,

E = reeving system efficiency.

The reeving system efficiency E is calculated as follows:

Equation 2-4 Reeving System Efficiency (Single Reeved System)

$$E = \frac{(K^N - 1.00)}{N(K^S)(K - 1.00)}$$

and

Equation 2-5 Reeving System Efficiency (Double Reeved System)

$$E = \frac{2(K^{N/2} - 1.00)}{N(K^{S/2})(K - 1.00)}$$

Where;

K = 1.00 plus percentage increase in the line pull to overcome the sheave friction and wire rope bending. For sheaves on bearings, K is taken as 1.02; for sheaves on bronze bushings, K is taken as 1.05. Sheave pitch diameters and wire rope construction are not considered.

S = number of running sheaves in the reeving system, including deflector sheaves that bend the wire rope 45 degrees or more.

$$DF = (MBF)/(P)$$

Where;

DF = design factor

MBF = wire rope minimum breaking force

Except where otherwise noted (e.g. SPS, standing rope, whip lines, mobile and articulating cranes), the required minimum design factor for running wire rope shall be 5.

Except for SPS and mobile and articulating cranes, the required minimum design factor for single part, rotation resistant rope shall be 8.

- (d) Single part whip hoists shall use ASTM A-1023 class 1 rotation-resistant wire rope (or equivalent) and be equipped with a roller or ball-bearing swivel.
- (e) Rotation resistant wire ropes shall not be used on luffing hoists.
- (f) Category 2 and 3 rotation resistant ropes shall not be used on single layer drums.

2-3.13.2 Permanent Wire Rope End Fittings.

- (a) Wire rope ends bearing full line pull shall have a permanent swaged or poured end fitting with the exception of mobile and articulating cranes. .
- (b) Swaged end fittings used on rotation resistant wire rope shall conform to EN13411 Part 8 and have approval of Navy Crane Center.

- (c) Swaged end fittings shall be selected in accordance with the swage fitting and wire rope manufacturer's recommendations. Swaged end connections shall be steel.
- (d) Poured fittings may be made with molten zinc or resin socketing material approved by Naval Ships Technical Manual (NSTM) Chapter 613, Wire and Fiber Rope and Rigging. Other resins shall be approved by Navy Crane Center.
- (e) Qualification of personnel who perform assembly of poured socket wire rope end connections shall be either in accordance with the socket OEM or in accordance with the NSTM Chapter 613.

2-3.13.3 **Non-Permanent Wire Rope End Retention Hardware.** Regardless of the type of retention, the ends of the wire rope shall be seized with 8 to 10 wraps of low carbon steel wire unless the ends are tapered and welded on a machine designed for that purpose.

2-3.13.4 **Standing Wire Rope Pendants.**

- (a) Wire rope used in stationary wire rope assemblies (standing rope) should be either improved or extra-improved plow steel, 6x36 or 6x19 class, bright (non-galvanized) or coated (galvanized), regular lay, with an independent wire rope core, and in all other respects in full compliance with Federal Specification RR-W-410, Wire Rope Users Manual, or ASTM A1023/A. Terminations shall be zinc or resin poured sockets or swaged fittings.
- (b) Except for SPS and mobile and articulating cranes, the required minimum design factor for standing wire rope pendant assemblies shall be 4, based on the wire rope minimum breaking force, and the dead and rated loads.
- (c) Standing wire rope pendants on new cranes shall have open, clevis style of fitting end connections.
- (d) Two-part pendants should be made with an intermediate short steel link between the adjoining end connections.
- (e) Closed end style of end connections shall engage the largest diameter pin or bolt that can be fitted.

2-3.14 **Reeving Systems. (Applicability includes commercial components)**

- (a) Hoists shall be double reeved, except single line whip hoists or if operational requirements dictate single reeving.

- (b) The design and arrangement of the load block shall be such that the wire ropes will not be pinched or cut in case of two-blocking.
- (c) Double reeved hoists, except for container cranes, shall be equalized.
- (d) When a hook hoist's wire ropes are routed parallel to the boom, there is minimal hook height movement relative to the boom due to luffing of the boom. This reeving arrangement should be specified for portal and floating cranes if desired by the activity.

2-3.14.1 **Overhauling Weight.** Portal and floating cranes and all cranes with single line hoists shall have a block of sufficient weight to overhaul the hoist ensuring wire rope tautness under no-load conditions.

2-3.14.2 **Fleet Angles.** Wire rope fleet angles entering or leaving sheaves and drum grooves shall not exceed the limits described in CMAA #70, ASME B30.16, and ASME HST as applicable, for bridge and gantry cranes, or the Wire Rope Users Manual for other crane types.

2-3.15 **Hooks.** (Applicability includes commercial components and paragraph 1-3.3 cranes with the exception of mobile and articulating cranes.)

- (a) Hooks shall be designed so that, using the straight beam method, the calculated combined stresses shall not exceed 20 percent of the material's ultimate strength or alternately, using the modified curved beam method, the calculated combined stresses shall not exceed 33 percent of the material's ultimate strength. Or 20 percent of the straightening load as obtained by hook manufacturer's testing.
- (b) Double barbed (sister) hooks should be analyzed with two maximum loads (50 percent of rated load each) applied 30 degrees from the shank centerline. The stress increasing effect of the hook curvature may be omitted.
- (c) Standard commercial hooks may be used at their published ratings when their published design factors are 5 or greater (3 if the curved beam theory is used with documentation). For non-SPS mobile and articulating cranes, standard commercial hooks may be used at their published ratings due to weight limitations.
- (d) Hook material shall be forged, carbon or alloy steel and exhibit a minimum elongation of 18 percent in 2.00 inches, except when anti-sparking characteristics are required. Where space permits carbon steel is preferred due to NDT periodicity requirements. Cast steel hooks may be used with Navy Crane Center approval.

- (e) Shank and nut threads shall have a Class 2 fit, per ASME B1.1.
- (f) Hooks shall have a means to prevent an attached item from coming free under a slack condition.
- (g) Hooks used to support personnel platforms shall be of a type that can be closed and locked, eliminating the hook throat opening.
- (h) Hooks shall not be welded, except by the original hook manufacturer prior to heat treatment.
- (i) Hooks shall be non-destructively tested (NDT) in accordance with NAVFAC P-307.
- (j) Hooks and nuts should be proof tested as an assembly in accordance with the hook proof test requirements of ASME B30.10.
- (k) An easily removable and reusable means shall be provided to positively secure the hook nut to the hook shank.

2-3.16

Load Blocks. (Applicability includes commercial components and paragraph 1-3.3 cranes with the exception of mobile and articulating cranes)

- (a) Custom designed blocks shall be analyzed for a minimum design factor of 5, based on material ultimate strength.
- (b) Load block components in the load path shall be steel. Stainless steel or bronze is acceptable if required by the operating environment. Ductile or malleable cast iron housings are permitted for packaged chain hoists.
- (c) The block design shall fully enclose the sheaves and wire ropes, except for wire rope slots and drain holes.
- (d) Block internal arrangement and clearances shall prevent the wire ropes from leaving the sheave grooves under any conditions.
- (e) For larger capacity cranes, the hook nut should rest on a thrust bearing mounted on a trunnion separate from the sheave pin that is free to swivel.
- (f) When the load block has four or more sheaves and the wire rope feeds from the drum to the inner block sheaves, those inner sheaves shall be a larger diameter than the adjacent sheaves to allow the ropes to clear the other wire ropes.
- (g) Block design shall allow the hook to rotate freely through 360 degrees while under test load without wire rope cabling.

- (h) The maximum bearing pressure of the trunnion on the side plate bores should not exceed 6000 psi, based on the projected area.
- (i) The ends of the trunnion shall be retained with keeper bars and their fasteners shall be lock wired.
- (j) The blocks shall be designed to permit easy removal of the hook without unreeving of the hoist.
- (k) Standard commercial blocks may be used at their published ratings when their published design factors are 5 or greater. For non-SPS mobile and articulating cranes, standard commercial blocks may be used at their published ratings due to weight limitations.

2-3.17

Spud Locks.

- (a) Spud lock pins shall be designed for the torque/load due to the maximum design wind velocity with the boom at maximum radius; on floating cranes, the loads due to list and trim shall be added to the wind load.
- (b) The shear stress design factors shall be 4 and 5 based on the material yield and ultimate shear strengths, respectively.
- (c) The bearing stress on the pin and its pocket bore shall have a design factor of 4 based on the material tensile yield strength.
- (d) The control circuitry shall be designed to disable the rotate drive when the spud lock is not fully disengaged and disable the spud lock actuator when the crane is rotating. The circuitry shall also include a momentary bypass switch to permit jogging of the rotate drive to free the spud lock pin if it is jammed due to drift of the upper works

2-3.18

Rotate Holding Brakes.

- (a) The combined capacity of the brakes multiplied by the mechanical advantage of the back-driven speed reducer shall be adequate for the imposed rotational loads that govern the design of spud locks.
- (b) The efficiency and operational characteristics of the back-driven speed reducer shall be confirmed with the manufacturer.

2-3.19 **Ratchet and Pawl Mechanisms.** On older portal cranes, the ratchet, its fasteners, the pawl, and the pivot joint were designed for 150 percent rated hook load to account for possible impact in engaging the ratchet. On newer cranes, designers shall use 150 percent of the rated hook load drum line pull for this design.

- (a) Boom hoists shall include a ratchet on the drum and a remotely actuated pawl mounted on the hoist foundation.
- (b) The control circuitry shall be designed to disable the boom hoist drive in the lowering direction when the pawl is not fully disengaged.
- (c) The drive shall not be disabled in the raising direction so that the drum can be rotated slightly to free and disengaged a wedged pawl.
- (d) All pivoting joints are required to have grease lubricated bearings
- (e) The pawl operating mechanism should include linkage which allows the pawl to maintain its position (either engaged or disengaged) without any additional power.

2-3.20 **Surface Finishes.**

- (a) Surface finish roughness height ratings in micro-inches for custom designed and machined components shall be as follows:

Items or Locations	Rating
Shaft seats for bearing inner races	63
Bearing housing bores for fixed outer race	125
Bearing housing bores for floating outer race	63
Bushing bores, rubbing surfaces of flanges	63
Rubbing surfaces of bushing flanges and thrust washers.....	63
Pins in bushings	32
Bores of gears, couplings, and wheels	63
Seats for gears, couplings, and wheels	125
Wire rope grooves (on drums and sheaves)	125
Keys, key seats, and keyways	125
Surfaces in contact with synthetic seal lips	16
Surfaces in contact with felt strip seals	63
Gears (working surfaces and root fillets)	63
Brake wheels (working surfaces)	63

- (b) All other shaft, axle, pin, bore, and mounting surfaces should be finished to a rating of 125. Any finer surface finish is satisfactory. For commercial off the shelf components, the manufacturer's provided finish is acceptable.

2-3.21 **Welding. (Applicability includes commercial components)**

- (a) Welding should comply with the applicable requirements of AWS D1.1 or D14.1. Otherwise welds shall be designed to provide the required design factors of mechanical components.
- (b) Typically, the strength of the weld metal is greater than the strength of the base metal; however, the required design factor is based on the strength of the base metal.

2-3.22 **Hydraulic Systems for Portal, Floating and Container Cranes.**

- (a) Hydraulic components, for which SAE standards are established shall comply with those standards. Components that do not comply with SAE standards, or are not included in them, shall be approved by the Navy Crane Center
- (b) Hydraulic fluids shall be petroleum based and compatible with all components and seals of the hydraulic systems; use of other hydraulic fluids shall be approved by the Navy Crane Center.
- (c) The maximum nominal operating pressure with rated load on the system should be limited to 2000 psi, with the pressure relief valves set at no higher than 3000 psi.
- (d) Stainless steel tubing, fittings, and pipes are recommended on all installations exposed to the weather and required for use on floating cranes.
- (e) Reservoirs shall not be less than 3 times the charge pump capacity.
- (f) Stainless steel fittings are recommended for all reservoirs and all associated fittings.
- (g) Filters shall have replaceable elements.
- (h) Filters shall be sized to limit the pressure drop across a clean element to not more than 10 psi at the operating fluid temperature and viscosity and to provide at least six months of service life at the anticipated level of crane operation.
- (i) Filter elements and housings shall have sufficient strength to prevent collapse or rupture under the most adverse operating conditions, and to withstand fatigue due to pressure or flow pulsations.
- (j) Filters are required that will limit the hydraulic system contamination to ISO range numbers of 18/17/14

- (k) Accumulators shall have a charging valve and a pressure gauge that are required at the top of the bladder, and an anti-extrusion valve at the hydraulic fluid port.
- (l) Accumulators shall have a manual bleed down valve at the outlet to release trapped pressure prior to any maintenance on it.
- (m) Control solenoid coils shall be rated for continuous current.
- (n) Threaded pipe connection shall be avoided.

2-3.22.1 **Hydraulic Travel Circuits.** Due to the complexities of plumbing these systems, electric travel drives should be provided on container and portal cranes, even when all other drives are hydraulic.

2-3.22.2 **Emergency Hoist Drum Brake System.**

- (a) The most efficient use of this system is as a third brake that does not set each time the hoist controller is returned to the off or stop position. When used as a secondary brake, the emergency hoist drum brake system shall be time-delayed to preclude torque lock-in under normal operation.
- (b) The brake process shall be controlled to avoid an impact greater than that used in the design load cases for the boom and other components.
- (c) The emergency brake shall set immediately in an emergency condition. This condition shall be taken into account during crane design.
- (d) Additional best set-up practices for these systems are provided in Appendix B.

2-3.23 **Carrier Yokes and Drive Heads. (Applicability includes commercial components)**

- (a) A minimum of one wheel on each side of the flange shall be driven to ensure adequate traction under all conditions.
- (b) The installation of a drive head is made at either or both of the outboard ends of the load bars – in place of the outboard carrier yokes shown in figure 2-4.
- (c) The travel assembly shall have at least one quarter of all wheels driven for indoor cranes, one half for outdoor cranes.

- (d) Manually powered geared trolleys should be equipped with anti-tilt rollers, which contact the underside of the monorail or bridge beams.

2-3.24 **Additional Container Crane Requirements. (Applicability includes commercial components)**

Container cranes require certain specialized pieces of equipment due to their mission and operating conditions.

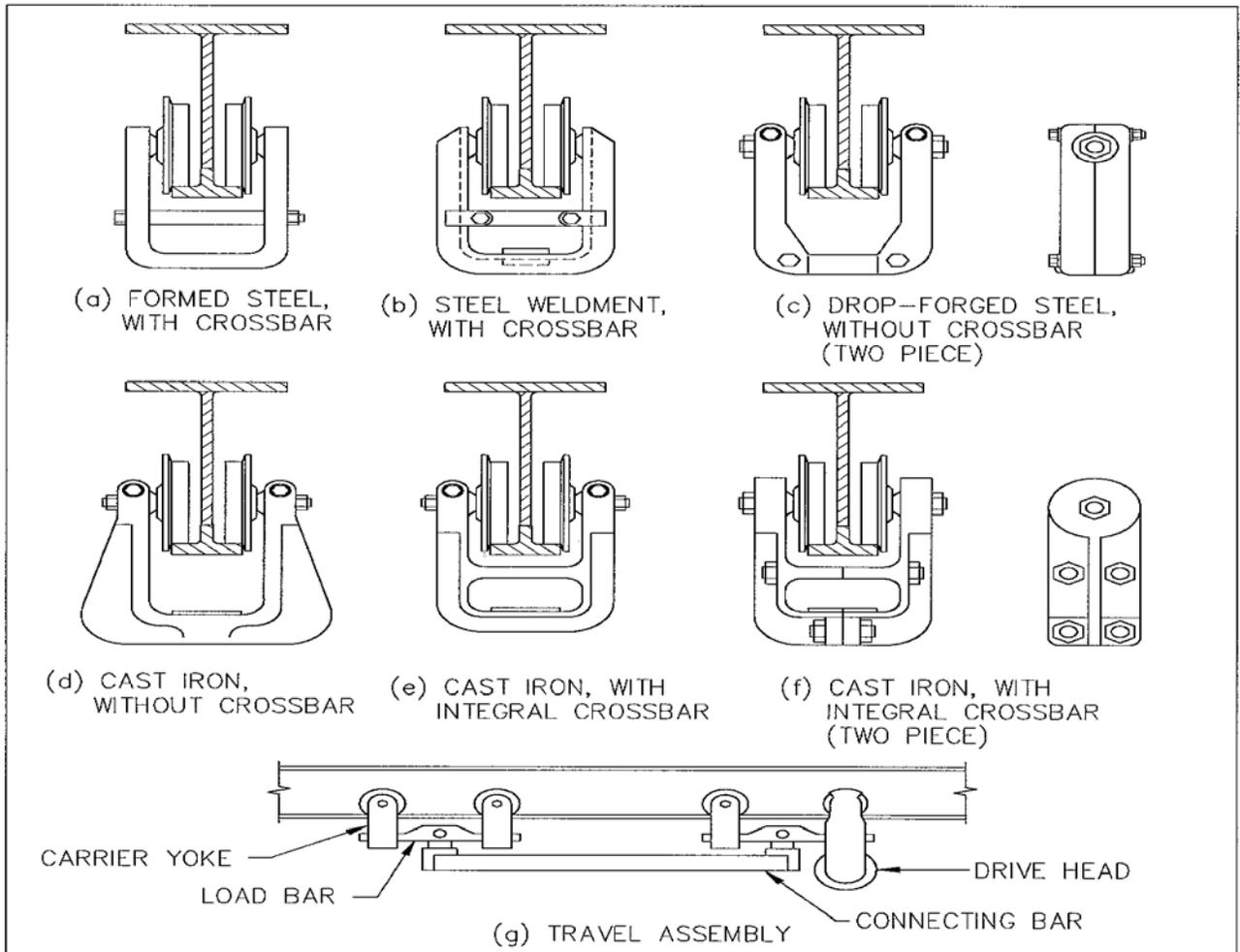
2-3.24.1 **List Trim and Skew Adjustment.** For controlling the rotation of container spreaders about any of the three principal axes to accommodate a ship's list, trip and skew, a container crane shall be provided with mechanisms to adjust the trim and list of its container spreader to plus or minus three degrees from the horizontal and a mechanism to adjust the skew plus or minus three degrees from the vertical.

2-3.24.2 **Snag Control.** This feature shall be provided to limit mechanical and structural loads to their design limits in the event of two blocking or contact between the container spreader and the ships cell. Worst case conditions shall be analyzed.

2-3.24.3 **Emergency Mode.** The design of the drive system shall allow emergency operation for the drives in the event a single drive inverter or motor fails.

2-3.24.4 **Wire Rope Re-Reeving Device.** A powered re-reeving device including all attachment points and ancillary equipment shall be provided with the crane. The design of this device shall consider all catenary and friction forces for the size of wire rope being re-reeved. This re-reeving device and equipment shall be located within the machinery house within the overhead crane operating envelope.

Figure 2-4 Carrier Yokes and Travel Assembly



2-4 MECHANICAL-ELECTRICAL. (Applicability includes commercial components)

Mechanical-electrical components, as applicable, shall be integrated into the crane's electrical system.

2-4.1 Sizing and Selection of Components. Except as stated otherwise, components shall be the industrial or marine grade products of manufacturers specializing in the production of this type of equipment.

2-4.2 Brakes. Unless otherwise specified, spring-set shoe, disc, and thruster brakes shall be designed in accordance with the applicable requirements of Part 10 of NEMA ICS 8 and AISE Standard No. 11.

2-4.2.1 **Mechanical Criteria for Brakes.**

- (a) On portal, floating, and container cranes, two spring set shoe brakes, each rated at 130 percent of rated load hoisting torque (minimum), shall be provided for each hoist drive mechanism.
- (b) All other cranes and hoists, with the exception of pneumatic and manual hoists, and mobile and articulating cranes shall have a minimum of two hoist holding brakes.
 - 1. The primary brake shall be located on the high speed shaft closest to the motor, with the secondary brake located closer to the wire rope drum in the drive train.
 - 2. The brakes may be either shoe or disc type, each rated at 130 percent of rated load hoisting torque (minimum).
 - 3. A mechanical load brake or self-locking worm gear may be utilized in lieu of one of the hoist holding brakes provided it stops and holds 130 percent of the hoist's rated load
- (c) If a caliper disc brake system is provided on the wire rope drum, it shall only set when the emergency stop is engaged, power is lost, or when a hoist drive train failure is detected(if equipped with a broken shaft detection system (BSDS)).
- (d) Hoist drive brakes should be adjustable down to 50 percent of their torque ratings by reducing the tension of the spring, which serves as the brake's setting mechanism. On drives where the brakes are utilized as holding brakes only, torque adjustment is not required and self-adjustment for friction lining wear is not recommended.
- (e) Except for brake wheels, spring-set shoe brakes shall be of all steel construction, including shoes, shoe levers, armatures, pull rods, torque springs, and bases.
- (f) Brake wheels may be steel or ductile cast iron.
- (g) When a caliper disc brake is utilized, the disc flange should be a demountable (two-piece) bolted steel ring or a replaceable wear segment on a permanent component.
- (h) Spring-set shoe or pad linings shall be of a non-asbestos material.

- (i) One spring-set shoe or disc brake, rated at 100 percent of rated motor torque (minimum), shall be provided for each travel drive mechanism and for each rotate drive mechanism on a portal crane.
- (j) Brakes for travel drives (bridge and trolley) for bridge and gantry cranes shall be sized in accordance with CMAA #70 or #74. Other outdoor cranes with powered motions (such as a powered jib) shall be provided with brakes sized to 100 percent of rated motor torque.
- (k) Travel drive and rotate drive brakes should be adjustable down to 50 percent of their torque rating by reducing the tension of the springs which serve as the brake's setting mechanism. On drives where the brakes are utilized as holding brakes only, torque adjustment is not required and self-adjustment for friction lining wear is not recommended.
- (l) Hydraulic brakes, when used, shall be capable of applying 130 percent of rated load hoisting torque based on an operator applied foot pedal force of 60 pounds.
- (m) When hoist wire rope drums are provided with a fail-safe caliper disc brake system the following requirements shall be met:
 - 1. The brake controls shall employ a failure detection system to set the disc brake mechanism whenever there is a 5 percent change in the ratio of drum shaft to motor shaft speeds.
 - 2. The disc brake mechanism shall have a torque rating of not less than 150 percent of rated load hoisting torque at the point of application and shall be designed such that failure of any single actuator would allow the remaining actuators to function.
 - 3. The energy which would have to be absorbed, with no contribution from the other brake(s) in the drive train, and dissipated during an emergency stop shall be taken into consideration.
 - 4. Metal components shall be steel with the exception of the brake housing, which may be gray or ductile cast iron.
 - 5. The brake pads shall be a non-asbestos material.
- (n) Spring-set brakes shall be equipped with a manual release mechanism that automatically resets when power is applied to the brake. The manual release for hoist brakes should be able to modulate the brake release force to assist in manual lowering of a suspended load in a controlled manner.

2-4.2.2 **Electrical Criteria for Brakes.**

- (a) Brakes, except hoist secondary brakes, shall be non-time delayed on setting.
- (b) On cranes with microprocessor travel controls brakes shall set after the associated controller decelerates the drive to a controlled stop.
- (c) On hoists with closed loop control systems, brakes shall set after the associated controller decelerates the drive to a controlled stop; load float may be utilized before setting of the brakes. On hoists with open loop control systems, brakes shall set immediately.
- (d) Hoist secondary brakes shall have a setting time delay between 1 and 3 seconds in any stopping condition including loss of power.
- (e) The time delay between primary and secondary hoist brakes is normally obtained electrically by a resistance-capacitance (RC) network or a resistor diode across the brake coil, and shall be maintained in cases of emergency stop or loss of power. The time delay shall not be accomplished using an uninterruptable power supply (UPS).
- (f) Brakes shall have non-time delayed release, with two exceptions:
 - 1. Hoist primary brakes may not release unless motor current is verified or torque is proven.
 - 2. When a hoist drive is equipped with a caliper disc brake system on the wire rope drum and a spring-set brake on the drive input shaft, the caliper disc brake system shall be released before the spring-set brake, and be time-delayed in setting during normal stopping.
- (g) The brake coil or solenoid time rating, if applicable, shall be the same as that of the associated motor.
- (h) If the hoist drive is equipped with a magnetically controlled single-speed or two-speed squirrel-cage hoist motor, the spring-set brake(s) shall be wired on the load side of the directional contactors and shall have a separate brake contactor.
- (i) On hoists with variable frequency closed loop controls, a mechanical load brake shall not be used.
- (j) On hoists with open loop variable frequency controls, a mechanical load brake shall be used.

- (k) Overcurrent protection for brake coil conductors shall be provided as required by paragraph 2-5.19.2(g).
- (l) Brake coil time ratings shall be selected for the duration and frequency of operation required by the service of the crane.
- (m) Brake release key switches for testing brakes independently shall be designed in one of the following ways:
 1. The key switch shall be designed as spring returned. The normal position of the key switch shall be the non-test mode, with all brakes fully functional.
 2. The brake release key switch may be a maintained switch, but shall be designed, such that no functions of the crane may be operated when any brake is in a released condition (except for the hoist down function for hoists with mechanical load brakes).

2-4.3 **Micro-Drives.** Micro-drives should not be used on new cranes.

2-4.4 **Clutches.** Clutches should not be used on new cranes with the exception of slip clutches used as load limiters on package hoists.

2-4.5 **Gearmotors.**

- (a) Gearmotors shall conform to AGMA 6019 and AGMA 6034, as applicable.
- (b) Shaft mounted gearmotors shall conform to AGMA 6009.

2-4.6 **Radius Indicators.** Cranes with luffing booms shall be equipped with a radius indicator.

2-5 **ELECTRICAL. (Applicability includes commercial components)**

- (a) NFPA 70, the National Electrical Code (NEC), CMAA #70, CMAA #74, ASME HST-4, SAE J1292, and various CFRs, prescribe the criteria that apply to virtually all electrical components of cranes. Other criteria beyond those are addressed herein. Some elements of those design criteria are recommendations (“should” statements), but are considered mandatory by the Navy Crane Center.
- (b) Only commercially available components that comply with the requirements of the National Electrical Manufacturers Association (NEMA) Industrial Control Systems (ICS) standards or of Underwriters Laboratories (UL) documents, or those of other

established nationally or internationally recognized approving organizations, may be used on Navy cranes.

- (c) Installation of electrical conductors and equipment shall comply with the NEC where that standard applies.
- (d) Low voltage wiring for mobile cranes applications shall follow the SAE J1292.
- (e) For installations where formal standards have not been established (e.g. portal cranes), the NEC is to be followed to the greatest extent practicable.
- (f) DOD-STD-2003 may apply to some crane applications on floating vessels.
- (g) Some electrical components may be used in either DC or AC systems; however, their DC and AC rating shall be noted because they may be significantly different.
- (h) Navy Crane Center is the “authority having jurisdiction” for all shore based Navy crane electrical installations.
- (i) The hazards of energized work and arc flash should be considered when specifying electrical crane requirements. Mitigation and control techniques such as arc flash calculations, hazard/risk category determination, Ingress Protection Rating 20 (IP20) “finger safe” designs, external user interfaces, and external frisk points should be considered.
- (j) Electrical components shall only be used in environments (i.e., temperature, humidity, etc.) allowed by the component manufacturer.

2-5.1

Electrical Installations.

- (a) Electrical connections shall be installed in accordance with NFPA 70 sections 110.14 or 430.9, as applicable, or as recommended by the device manufacturer.
- (b) Crimped terminal lugs, if used, shall be properly sized for the wire and installed using the device(s) (e.g., crimping tool and indenter) recommended by the terminal lug manufacturer.
- (c) Spare conductors should be identified as such, and shall have their ends insulated to preclude accidental contact with energized equipment.

- (d) Adhesive-backed wiring tie wraps and cable-clamping devices should not be used unless they are secured with fasteners, in addition to the adhesive.
- (e) Wiring around sharp edges, such as panel doors, should be wrapped in protective sleeves (e.g., “spiral wrap”) to prevent wiring insulation damage from chaffing, cutting, or abrasion.
- (f) Control panels should not be used as raceways for conductors not terminating within the panel.
- (g) Bushings or chafing protection gear should be used on all panel conduit entries.
- (h) Only equipment that needs to be viewed or accessed from the panel door (i.e. dataloggers, key switches, pilot lights, etc.) should be mounted on the panel door.
- (i) A non-resettable hour meter, connected across the main line contactor to indicate the elapsed number of hours the crane is energized should be provided on all cranes.
- (j) A non-resettable hour meter for each function connected to each function’s brake contactors to indicate the running time of each individual function should be provided on all cranes.
- (k) All electrical components are required to be located so they are easily accessible for inspection and maintenance.

2-5.2 **Ancillary Systems.**

- (a) Conductor ampacities for continuous loads such as utility, heating, lighting, air conditioning, etc, shall be determined by using NEC Table 310.15(B)(16) or by multiplying the load by 2.25 and using NEC Table 610.14(A).
- (b) Receptacles shall be ground-fault circuit-interrupter protected type or supplied from circuit breakers providing ground-fault circuit-interrupter protection for personnel.
- (c) Refer to section 2-5.19 for requirements for ancillary circuit overcurrent protection and disconnecting means.
- (d) Ancillary systems should not be powered by control transformers.
- (e) Refer to section 2-5.23 for specific requirements for lighting.

2-5.3 Diesel Engine-Generator Sets.

- (a) Diesel engines shall be sized so that the crane drive with the largest motor(s) can be accelerated to its rated speed while the two drives with the next largest motors are operating at rated load/rated speed plus ancillary power requirements. Generators shall be selected based upon the power required to simultaneously accelerate the three largest drives operating at rated load plus ancillary power requirements.

The diesel engine of a portal crane is recommended to be selected, based on its prime rating, utilizing the following formula:

Equation 2-6 Diesel Engine Prime Rating

$$D = (1.5)(T) + (H) + (M) + (1.675)(A)$$

Where: D = Diesel engine prime rating in horsepower;
T = minimum calculated running travel drive horsepower;
H = minimum calculated running main hoist horsepower;
M = minimum calculated running horsepower for the third largest drive; and,
A = ancillary loads (transformer rating in kVA).

The generator of a portal crane is recommended to be selected, based on its continuous rating, utilizing the following formula:

Equation 2-7 Generator Continuous Rating

$$G = (1.12)(T + H + M) + (1.25)(A)$$

Where: G = generator continuous rating in kilowatts;
T = minimum calculated running travel drive horsepower;
H = minimum calculated running main hoist horsepower;
M = minimum calculated horsepower for the third largest drive; and,
A = ancillary loads (transformer rating in kVA).

- (b) Diesel engines used on portal, container, and gantry cranes shall comply with the Environmental Protection Agency regulations at 40 CFR Part 89 or Part 1039 as applicable.
- (c) A speed governor is required to maintain the speed within predetermined limits.
- (d) DC generators are limited to two types – flat compound-wound for constant potential control systems, and separately excited shunt-wound for adjustable voltage control systems.

- (e) The set location shall ensure an adequate flow of cooling air and a slight negative pressure with respect to the adjoining spaces.
- (f) The exhaust system should be entirely of stainless steel and shall include a spark arresting silencer and a bellows type duct section to compensate for expansion/contraction of the exhaust duct between its anchor points.
- (g) The mandatory diesel engine instrumentation includes the engine speed (RPM) tachometer, coolant temperature gauge, and the lubricating oil pressure gauge. The tachometer and gauges shall be installed in the operator's cab and in the diesel engine operations space.
- (h) Electronic speed and fuel controls shall be specified for all new crane procurements.
- (i) The diesel engine and generator shall be mounted on a common foundation, and coupled by a coupling designed for this application. The diesel engine generator foundation shall be mounted in the crane on vibration isolators/dampers (unless engine generator OEM recommends different damper placement) to reduce engine vibration transmitted to the crane structure.
- (j) The coupling between the diesel engine and generator shall be selected based on a torsional vibration analysis performed on the diesel engine and generator as a set. The analysis shall consider both full load and no load operation of the diesel generator set.
- (k) An hour meter shall be provided to continuously register the hours of engine operation.
- (l) Audible and visual alarms for engine overspeed, high coolant temperature, and low lubricating oil pressure are required in the operator's cab. For electronic engine controls where overspeed alarm and shutdown are not required by the engine manufacturer, the audible and visual alarm indication may be omitted from the operator's cab.
- (m) When any of the audible and visual alarms settings are exceeded beyond the engine manufacturer's limits, the engine control system shall automatically shut it down.
- (n) On portal cranes, the fuel system shall be arranged to facilitate refueling from ground level.
- (o) On floating cranes, the diesel engine shall be fueled from a "day tank" on the crane; and the main tank is installed in the barge.

2-5.4 **Motor-Generator Sets.**

- (a) The motors and generators shall be rated for continuous duty operation.
- (b) The motor shall be sized for simultaneous operation of specific drives.
- (c) The motor-generator set is to be provided with a reduced-voltage type squirrel cage motor starter with thermal overload protection, a generator field quenching circuit, and edgewound generator field resistors where field control resistors are used.
- (d) Generator output voltage is to be varied by electronic voltage regulator magnetic field relays to shunt out segments of the field resistors or by the use of a manually operated rheostat.

2-5.5 **Motors and Encoders.**

- (a) CMAA #70 calculations for motor horsepower shall be used in selecting bridge, trolley, and hoist drive motors on bridge cranes.
- (b) Bridge motor horsepower selection for outdoor bridge cranes is dependent on the wind area of the crane. These motors shall be sized using the applicable sections of CMAA#70.
- (c) Calculations for floating cranes shall account for the effects of the list and trim of the barge on motor loading.
- (d) Calculations for travel drive motors on portal cranes are required to take into account the unique loadings attributable to the crane starting up and traveling through curves.
- (e) For both rotate and travel drives (on portal, floating, and container cranes), the effects on motor loading of drive operation with one rotate drive motor or a pair of travel drive motors out of service shall be considered.
- (f) The travel motors on a portal crane are required to have a combined total 60-minute horsepower rating of not less than as determined by the formula:

Equation 2-8 Horse Power Rating

$$HP = (850.75 \times 10^{-9})(W)(V)$$

Where: W = total weight of crane plus hook load, in pounds; and,
 V = rated travel speed of crane, in feet per minute.

- (g) Motor insulation shall be Class F minimum.
- (h) If a closed loop variable frequency controller is used, the drive motor shall be an AC single speed vector duty, with encoder or other motor shaft speed feedback device.
- (i) If an open loop variable frequency controller is used, the motor shall be an AC single speed inverter duty type.
- (j) Motors used on cranes shall be a minimum of 60 minute duty rated motors. 30 minute motors may be used with Navy Crane Center approval.
- (k) Motors shall be equipped with thermal overload protection and overcurrent protection. Refer to 2-5.19 for requirements.
- (l) AC motors shall be Totally Enclosed Non Ventilated (TENV), Totally Enclosed Fan Cooled (TEFC), or Totally Enclosed Blower Cooled (TEBC).
- (m) Consideration should be given to the maintenance requirements of the blower motors when using TEBC motors.
- (n) Refer to 2-5.11 for motor branch circuit conductor requirements.

2-5.5.1 **DC Drive Motors.**

2-5.5.1.1 **Series-Wound Motor Drives.**

- (a) A resistance in parallel with the armature shall be installed to limit the maximum speed in the first one or two hoisting speed points.
- (b) On hoist drives, to avoid overhauling during lowering the series-wound motor shall include circuitry which automatically reconfigures motor armature and field connections into a shunt-wound (constant-speed) design.
- (c) Field weakening during operation to increase motor speed greater than base operating speed shall not be allowed.

2-5.5.1.2 **Shunt-Wound Motor Drives.** Shunt-wound motors shall have the armature and field winding connected independently.

2-5.5.2 **Encoders.**

- (a) Encoder conductors should have a continuous run from the encoder to the drive. If a continuous run is not possible, connection points for the encoder conductor shall be made in an isolated junction box containing no other conductors.
- (b) If the length of cable required between a drive and its respective encoder is longer than 300 feet, fiber optic cable should be used.
- (c) Encoders should have a minimum resolution of 1024 pulses per revolution (PPR).

2-5.6 **Control Equipment.**

- (a) Each motion of a crane shall be controlled by a separate control system (drive).
- (b) Reversing contactors shall be electrically and mechanically interlocked between directions.
- (c) Bridge and trolley motor stepped control systems on bridge cranes, rotate motor stepped control systems on portal and floating cranes, and travel motor stepped control systems on portal cranes shall be provided with a drift point between OFF and the first speed control point in each direction if the crane is equipped with an operator applied brake (e.g. hydraulic foot brake).
- (d) All Emergency Stop pushbuttons, upon actuation, shall remove all power from all drive motors and brakes, and microprocessor drives, if present. Note: on all crane types the Power Off button also serves as the Emergency Stop, although there may be additional Emergency Stop pushbuttons.
- (e) Emergency Stop (power off) pushbutton(s) circuitry shall be independent of microprocessor drives, if present.
- (f) No neutral wire shall pass through the contacts of an AC powered control relay or contactor, i.e., a device shall not be shut off or disengaged by breaking the device's neutral conductor (regardless of whether the device controls AC or DC components).
- (g) Roll-up on hoist functions shall be less than 1/8" measured at the hook block and roll back shall not occur over the entire load range of the hoist.
- (h) Non-time delayed brakes shall be set upon main line contactor de-energization.

- (i) Under voltage protection shall be provided for all motor control systems.
- (j) Refer to section 2-5.22 for requirements for transient and harmonics protection for microprocessor drives.
- (k) On cranes with microprocessor drives, Navy Crane Center recommends that a crane designed parameter range be obtained from the crane OEM for each parameter which is anticipated to need adjustment during the life of the crane. This crane designed parameter range shall be the applicable portion of the drive's default range for each parameter and shall be the range in which each parameter can be safely tuned by the end user. At a minimum, the ranges for acceleration and deceleration parameters should be obtained.
- (l) For hoists utilizing brake failure detection, a dedicated indicating light shall be provided to alert the operator of a brake failure.

2-5.6.1 **AC Control Equipment.** Motors shall be energized at a frequency not exceeding 60 Hz at the highest speed without Navy Crane Center approval (Operation above 60 Hz may entail mechanical drive train rpm limiting considerations).

2-5.6.1.1 **AC Magnetic Control.**

- (a) Plugging is prohibited on travel drives with NEMA Design B squirrel cage motors. Device(s) shall be provided to preclude unintentional plugging when these motors are utilized.
- (b) For bridge and trolley drives with squirrel cage motors, an electrical torque reduction unit (soft start) is recommended. If utilized, the unit shall be sized to provide sufficient starting torque to initiate motion of the motor from standstill with rated load under the hook.
- (c) The control system for a wound-rotor motor shall be provided with resistive or reactive secondary controls.

2-5.6.1.2 **AC Variable Frequency Drive Control.**

- (a) AC variable frequency (open loop and closed loop) controllers shall meet NEMA ICS 8, part 8.
- (b) AC variable frequency (open and closed loop) controllers used as hoist drives shall be selected such that the continuous rating of the controller is not less than 130 percent of the calculated full load motor current based on CMAA #70, paragraph 5.2.9.1.1.1 (or equivalent) and NEC Table 430.250.

- (c) AC variable frequency open loop and volts per hertz drives used for hoisting functions shall be equipped with a mechanical load brake. The ratio of high speed to low speed is recommended to be no higher than 10:1.
- (d) The ratio of high speed to low speed is recommended to be no higher than 20:1 for variable frequency volts-per-hertz and open loop drives used for travel functions.
- (e) Slow speed functionality operated by a switch on the controller is recommended to be used for all functions on cranes with variable frequency drive control. This slow speed mode is recommended to be set between 25 percent and 10 percent of the rated speed of each function.
- (f) AC variable frequency closed loop controllers used in hoist functions are required to enable the motor to develop rated torque continuously at zero speed. The ratio of high speed to low speed should not be higher than 100:1 unless special design considerations are provided which may enable higher ratios.
- (g) Each variable frequency drive is required to include, as a minimum, electronic instantaneous over current protection, DC bus over voltage protection, and the ability to withstand output line-to-line shorts without component failure.
- (h) Motors shall run smoothly without torque pulsations or dithering at the slowest speed.
- (i) Dynamic braking shall be provided. Long lifts at slow speeds may require special resistor sizing and maximum temperature considerations.
- (j) Closed loop controls shall provide torque proving for hoist functions. Torque proving is a drive feature that ensures adequate motor torque is available to suspend the load before the hoist brakes are released.
- (k) The secondary brake on a closed loop control system shall be connected to a different output (within the drive or independent of the drive) from the primary brake.

2-5.6.2 **DC Control Equipment.**

- (a) Fuses shall not be used in motor loop circuits.

- (b) Motor direction shall be changed by reversal of armature voltage polarity.
- (c) Weakening of motor field strength during motor operation shall not be permitted.
- (d) Non-time delayed brakes shall be set upon main line contactor de-energization.

2-5.6.2.1 **DC Magnetic Control.**

- (a) When shunt-wound DC motors are connected in parallel, as in the rotate drive on a portal or floating crane, resistance shall be connected in series with each armature for load equalization.
- (b) When armature shunting is used to limit the hoisting speed of a lightly loaded motor, armature shunt resistor selection shall be verified for across-the-line current because it could initially draw an equivalent current during plugging.

2-5.6.2.2 **DC Microprocessor Drive Control (DC Digital).**

- (a) Microprocessor based adjustable voltage DC control systems (DC digital), shall include as a minimum:
 1. Fully rated four-quadrant motor control.
 2. Faults for speed deviation and any steady state speed.
 3. Faults for instantaneous phase loss or incorrect phase sequence.
 4. Faults for semiconductor failure or loss of firing pulse.
 5. Motor overspeed for hoist functions.
 6. Torque proving for hoist functions. Torque proving is a drive feature that ensures adequate motor torque is available to suspend the load before the hoist brakes are released.
 7. Instantaneous overcurrent protection.
- (b) Microprocessor DC control systems shall provide automatic regenerative braking for speed-reduction and slow down before spring set brake setting and, for hoist drives, dynamic braking, when the control is in the OFF position, and emergency dynamic braking to limit hook speed to a maximum of 50 percent of rated hoisting speed with rated load on the hook, in case of power failure

or opening of any fuse or circuit breaker that affects control of the load.

- (c) Speed regulation shall be 1.0 percent with tachometer feedback and 5.0 percent with armature voltage feedback regardless of load.
- (d) A $-600V-0-+600V$ volt meter, indicating thyristor bridge output voltage for each drive, shall be viewable to the operator and on the drive's control panel.
- (e) An ammeter, indicating current in the motor loop circuit, shall be on each control panel and, for hoist drives, viewable to the operator.
- (f) Contacts of motor loop contactors shall be silver-laminated copper.

2-5.7

Contactors and Relays.

- (a) Electrically powered cranes, including chain and wire rope hoists, shall have a main line contactor which shall be wired to remove power from all motors and brakes.
- (b) Energization of the main line contactor shall be controlled by the POWER OFF-POWER ON pushbutton at the operator's station.
- (c) Except for the POWER OFF-POWER ON circuit, the control circuit including directional contactors should not be energized without energization of the mainline contactor.
- (d) A hoist line contactor, which shall be wired to remove power from all hoist motors and brakes, should be used on hoists controlled by microprocessor drives.
- (e) The hoist line contactor or mainline contactor shall be opened during actuation of the secondary or final hoist upper limit, with the exception of magnetic controlled chain hoists with overload clutches.
- (f) When reversing magnetic contactors are used on cranes the contactors shall be electrically and mechanically interlocked.
- (g) When more than one control station is provided, electrical interlocks shall be included in the system to permit operation from only one station at a time. This interlocking may be performed by relay contacts.
- (h) The use of definite purpose contactors on cranes, where not originally provided by the manufacturer, is prohibited.

- (i) For DC motors and AC wound-rotor motors, the requirements of NEMA ICS 8 for controllers shall be met.
- (j) The minimum size of DC contactor is recommended to be NEMA Size 3.
- (k) For AC squirrel cage motor controllers, the requirements of NEMA ICS 2, Part 8, for general-purpose controllers, shall be met.
- (l) If IEC contactors are used, the application cannot exceed the contactor manufacturer's AC3 ratings for the contactor.
- (m) Contactors and relays used with variable frequency drives shall have appropriate MOVs or R-C surge absorbers installed across the respective device's coil.

2-5.8 **Thyristors (SCR's) for DC Drives.**

- (a) The conversion unit shall be in the three phase, full wave configuration
- (b) The rectifier bridge shall be rated, based on RMS values, for continuous duty at a minimum of 150 percent of the highest motor current rating that will provide full torque at all speeds, and for 300 percent of this motor current rating for one minute.
- (c) The peak inverse voltage rating shall be greater than 200 percent of the working peak inverse voltage.
- (d) Thyristor case temperatures shall be less than 212 degrees Fahrenheit in an 86 degree ambient when delivering rated current.
- (e) Parallel operation of thyristors is not permitted.
- (f) The maximum DC average voltage shall be less than 500 volts

2-5.9 **Rectifiers (Power Diodes).**

- (a) The rectifier bridge shall be rated for continuous duty at a minimum of 150 percent of the load rating, and at a minimum of 300 percent of the load rating for one minute.
- (b) The peak inverse voltage rating relative to the working peak inverse voltage shall be greater than 200 percent for avalanche type diodes and greater than 250 percent for other types.

- (c) Diode case temperatures shall be less than 212 degrees Fahrenheit in an 86 degree ambient when the diodes are delivering rated load.
- (d) When parallel operation of diodes is utilized, each diode's actual share of the load shall differ from its calculated share by less than 10 percent.
- (e) Purposely matched diodes shall not be used;
- (f) Current-equalizing devices shall be provided to force diodes to share current.
- (g) The current on the legs of the bridge circuit shall be balanced to within 5 percent.
- (h) The DC average output voltage shall be less than 500 Volts.
- (i) Regenerated power shall be automatically absorbed by resistors or other devices.
- (j) Minimum protection for the power diodes shall consist of a line isolation transformer, transient surge suppressors, or current-limiting rectifier type fuses.

2-5.10

Resistors.

- (a) Resistance thermal capacity shall be based on the continuous duty rating at the maximum calculated steady state current.
- (b) Power resistors shall be fabricated of stainless steel or other corrosion resistant metal.
- (c) The use of "wirewound" type resistors is not recommended for segments of 8 ohms or less.
- (d) Power resistors shall be mounted in substantial enclosures designed to permit the free flow of air sufficient to cool the resistors by natural convection when operating within their current rating.
- (e) When the resistor enclosure is mounted outdoors, it shall be fabricated from stainless steel.
- (f) Dynamic braking resistors shall be sized per microprocessor drive manufacturer's requirements (also see paragraph 2.5.6.1.2(i)).

2-5.10.1 **Load Banks.** When regenerative power exceeding 50 percent of the diesel engine's friction power rating is sensed, the load bank shall be connected across

the generator to absorb the regenerative power. When regenerative power being sensed is less than 50 percent of that rating, the load bank shall be disconnected. If regenerative power is always less than 50 percent of the diesel engine's friction power rating, a load bank is not required.

2-5.11 Conductors.

- (a) NEC Article 310.15 shall be used when sizing conductors for continuous use such as ancillary equipment. NEC Table 610.14(A) can also be used for sizing conductors for continuous use when the load is multiplied by a factor of 2.25 (see section 2-5.3).
- (b) NEC Table 610.14(A) shall be used when sizing conductors for crane and hoist motors.
- (c) Motor branch circuit conductors shall be sized at a minimum of 150 percent of the motor's nameplate full load amps and shall not be less than 12 American Wire Gauge (AWG).
- (d) Temperature correction factors are shown in NEC Tables 610.14(A), 310.15(B)(2)(A), and 310.15(B)(2)(b). These correction factors shall be used when selecting conductors.
- (e) Where flexibility is required in control circuit wiring, such as operator's consoles and chairs, selection of flexible cords and cables from NEC Table 400.4 is permitted. Also, the use of single conductor portable power cables is permitted. However, they shall be routed in raceway and their ampacity shall be considered to be the 167 degrees (Fahrenheit) ampacity listed in NEC Table 310.16 or NEC Table 610.14(A), as appropriate for the application. Other ampacities published for portable power cables would be based upon their heat dissipation in free air and not that in raceway. As these cables are being installed in raceway, rating would have to be based upon that use.
- (f) For wiring on crawler, truck and mobile cranes, the standards of SAE J1292 apply. This standard may also be used for the engine harness wiring of diesel generator sets. DOD-STD-2003 may apply to some crane applications on floating vessels.
- (g) Voltage drop for runway conductors shall be no greater than 3 percent from the nominal system voltage at the point of runway conductor collection farthest from the runway conductor supply tap.
- (h) Voltage drop for motor conductors shall not be greater than 2 percent from the runway collection point to the motors.

- (i) Aluminum conductors shall not be used. Aluminum connectors are allowed if they are rated for use with copper conductors (marked "AL/CU").
- (j) All wiring shall be numbered or tagged at connection points.
- (k) All conductors connected to or routed above resistors shall have insulation shown in NEC Table 610.14(A) for 257 degrees Fahrenheit maximum temperature.
- (l) Conductors shall be landed on terminal strips and not spliced at connection points. Exceptions are:
 - a. Motor and brake connections may be made using split-bolts or lugged and connected with nuts, bolts, flat washers and lock washers in lieu of installing a terminal block in the motor connection box. Wire-nuts shall not be used.
 - b. Connections for lighting ballasts may be made using wire nuts.
- (m) Conductors should be continuous between the source and termination point for devices (such as encoders and load cells) that use shielded cables to transmit data.
- (n) Spare conductors shall be identified as such, and shall have their ends insulated to preclude accidental contact with energized equipment.
- (o) For interconnecting wiring, stranded conductors of any construction shall comply with NEC Table 310.104(A), with the following exceptions:
 - 1. Those containing asbestos in the insulation or outer covering are prohibited.
 - 2. For DC circuits in wet locations (i.e. in raceways exposed to the weather and unprotected) electroendosmosis shall be considered if choosing thermoplastic insulation.

2-5.12

Raceways.

- (a) Conduit fill shall be calculated and meet the requirements of NEC, Chapter 9. For a cable, either shielded and unshielded, or a conductor with stranding not included in NEC Chapter 9, run in conduit, its actual cross-sectional area shall be used in the calculation of percentage of fill.

- (b) The cross-sectional area of equipment grounding conductors shall be included in the calculation.
- (c) As much as practical, power and control cables should not be mixed in the same conduit in order to prevent interference.
- (d) Low voltage signal cables and power cables shall not be mixed in the same conduit.
- (e) Excluding conduit directly connected to dynamic breaking resistors, raceways shall maintain a minimum of 12 inches clearance between the raceway and dynamic braking resistors.
- (f) All raceways shall be supported at distances as required by NEC for the specific type of raceway being used.
- (g) Flexible conduits such as liquid tight should only be used where flexibility due to vibration is required, such as at motor terminals.

2-5.13 Eddy-Current Brakes.

- (a) Eddy-current brakes shall be rated to produce not less than the following percentages of rated hoist motor torque: 75 percent at 1/8 full speed; and 112.5 percent at 1/4 full speed.
- (b) An eddy-current brake shall be excited with reduced voltage when the control is in the OFF position.
- (c) When an eddy-current brake is utilized, a permanent magnet alternator and rectifier shall be used to provide reduced voltage excitation of the eddy-current brake for emergency dynamic braking for a maximum terminal velocity of 40 percent of the rated hoisting speed with rated load on the hook.
- (d) Operation of a hoist drive on any eddy-current brake controlled point shall be prevented upon loss of brake excitation.

2-5.14 Control Panel Enclosures.

- (a) NEMA type 12 metallic enclosures should be provided for standard indoor use, when there is no requirement for corrosion, water, or dust protection.
- (b) NEMA type 4X metallic enclosures should be provided for outdoor use.

- (c) NEMA ventilated Type 1 enclosures should be provided for constant potential DC controllers to permit the migration of ozone from the enclosure.
- (d) Where condensation problems are known to exist or when required by the controller manufacturer a thermostatically controlled anti-condensation heater shall be installed in each control panel enclosure. Anti-condensation heater power supplies shall remain energized when the crane is off.
- (e) Consideration should be given to installation of a nominal 120 VAC system, receptacles, and panel lights controlled by a door switch for maintenance purposes.
- (f) Refer to section 2-6.2 for requirements for control panels in hazardous or explosive environments.

2-5.15

Limit Switches.

- (a) Primary (adjustable) lower and upper limit switches of the control circuit type are required for all hoists. Overload clutches that meet the requirements of ASME B30.16 are acceptable alternatives to upper and lower limit switches for magnetic controlled electric chain hoists and pneumatic hoists. For closed loop microprocessor controlled cranes, software activated limits based on encoder feedback are acceptable as primary limits.
- (b) Primary upper limit switches shall be designed such that activation shall allow movement only in the lowering direction. Lowering of the block (or boom) shall automatically reset the primary limit switch.
- (c) Primary lower limit switches shall be designed such that activation shall allow movement only in the raising direction. Raising of the block (or boom) shall automatically reset the primary limit switch.
- (d) Limit switches activated from wire rope drum turns (geared limit switches) are recommended for hoist primary limit switches. Rope guided switches and proximity switches are not recommended for hoist primary limit switches.
- (e) A secondary upper limit switch, wired independent of the directional contactors and of the primary limit switch, such that its activation will result in the removal of power from the motor and brake via a hoist line contactor or mainline contactor is required on all hoists, except for pneumatic hoists and electric chain hoists. The secondary upper limit switch shall be block (or boom) activated unless otherwise approved by the Navy Crane Center.

- (f) For microprocessor controlled electric chain hoists, the final upper hoist limit switch shall be wired to remove all power from the hoist drive motor and brake(s) independent of the microprocessor drive.
- (g) A three-position spring-returned keyed bypass/reset switch should be included in all crane designs. The keyswitch shall allow for bypassing of the primary upper limit switch to allow for testing of the secondary limit switch and shall allow resetting of the secondary upper limit switch prior to resuming operation. During resetting of the secondary limit, the hoist shall operate in the lowering direction only.
- (h) For microprocessor controlled electric chain hoists, a two-position spring-returned bypass switch shall be provided that allows for resetting the final limit switch prior to resuming operation. During resetting of the final limit, the hoist shall operate in the lowering direction only.
- (i) Runout distances shall be computed with no load on the hook.
- (j) The lower limit switch shall be set such that there are a minimum of two wraps of rope on the hoist drum (three wraps for ungrooved drums) upon limit switch actuation.

2-5.15.1 **Motion/Position Limits (Bridge, Gantry, and Semi-Gantry Cranes).**

- (a) The primary upper limit switch setting shall be set at not lower than the required hook height.
- (b) The secondary upper limit switch shall be set not lower than the hook height of the primary upper limit switch setting plus the primary runout distance, but not less than the secondary runout distance below the lowest contact point of the hoist or trolley structure (two-block condition).
- (c) Where the use of a slow-down limit switch is required based on hook speed and lift requirements, the limit switch shall be set below the primary upper limit switch to automatically decrease the hoisting speed to a predetermined slow speed before tripping the primary upper limit switch.
- (d) Bridge and trolley motion limit switches may be required. If required, bridge and trolley motion limits shall be of the control circuit type.

2-5.15.2 **Motion/Position Limits (for Portal and Floating Cranes).**

- (a) Luffing hoist limit switching shall be provided to:
 - 1. prevent raising the boom above the angle which puts the main hoist hook at its minimum operating radius
 - 2. prevent lowering the boom below the angle which puts the main hoist hook at its maximum operating radius.
 - 3. prevent lowering the boom beyond horizontal
 - 4. bypass the main and other hook hoist upper limits (with a horizontal boom) whenever the boom is at or above the angle which puts the main hoist hook at its maximum operating radius.
- (b) A boom-actuated upper limit switch shall be provided as an emergency back-up of the primary upper limit switch, by causing power interruption to the hoist motor and brakes through a means different from that used by the primary limit switch (for example, by opening a line contactor).
- (c) A bypass keyswitch shall be provided that has the capability to bypass the emergency back-up boom upper limit switch and lower (not lift) the boom with the emergency back-up switch tripped.
- (d) Main hoist limit switching shall be provided to:
 - 1. prevent raising the hook beyond its maximum elevation with the boom at the angle which puts the main hoist hook at its maximum operating radius;
 - 2. prevent raising the hook beyond its maximum elevation with a horizontal boom unless automatically bypassed whenever the boom is at or above the angle which puts the main hoist hook at its maximum operating radius;
 - 3. prevent lowering the hook beyond its minimum elevation with boom at the angle which puts the main hoist hook at its minimum operating radius.
 - 4. When a hook hoist's wire ropes are routed parallel to the boom, there is minimal hook movement relative to the boom due to luffing of the boom. Therefore, limit switch configuration should be carefully considered.
- (e) Limit switches shall be used with a spud lock to:

1. limit the upward and downward movement of the spud
 2. to energize and de-energize lights indicating the engagement or disengagement of the spud
 3. to indicate to the operator the position of the spud, relative to the socket, when they are within close proximity while the upper works rotates
- (f) Limit switches used for spud locks shall be configured to prevent operation of the rotate drive when the spud is not fully retracted.
- (g) Limit switches shall be used with boom pawl mechanisms. Limit switches shall be used to determine the position of the pawl so that:
1. its full engagement and full disengagement can be indicated to the operator
 2. its engagement is prevented while lowering the boom
 3. boom lowering is prevented unless the pawl is released
- (h) Circuitry shall be used to prevent engagement of pawl during the time the boom is commanded to stop from a lowering motion until it has actually ceased movement.

2-5.16

Controllers.

- (a) Controllers shall be clearly and permanently labeled with functionality and direction. Directional markings shall match the markings for direction located on the crane.
- (b) Controllers for bridge cranes and hoists shall have their controls arranged per CMAA #70 or CMAA #74 unless other standardization exists at a facility.
- (c) Each operator station is required to have a black POWER ON pushbutton and a red mushroom head STOP/POWER OFF pushbutton. Alternatively, the POWER ON and STOP/POWER OFF pushbuttons may be combined in a single red push/pull button; the POWER ON function shall be a momentary type pull function.
- (d) Pushbuttons, except the STOP/POWER OFF pushbutton, shall be guarded to prevent accidental actuation.
- (e) Energization of the main line contactor shall be controlled by the STOP/POWER OFF-POWER ON pushbutton.

- (f) Refer to section 2-5.7 for requirements for interlocking when more than one control station is provided.

2-5.16.1 **Pendant Pushbutton Stations.**

- (a) A method of strain relief shall be provided with all pendant pushbutton stations to protect the electrical conductors from strain. Recommended method is a stainless steel wire rope strain lead having a diameter of 1/8 inch (minimum) or an internal strain relief cable built into the multiconductor cable.
- (b) The minimum wire size of multiconductor flexible cords for pendant pushbutton stations shall be #16 AWG.
- (c) Pendant pushbutton stations shall have a grounding conductor between a ground terminal in the station and the crane.
- (d) The pendant pushbutton station shall be rated appropriately by NEMA for the environment in which it will be used in with the exterior being made of non-conductive material.
- (e) Pendant pushbuttons shall be spring return to the OFF position.
- (f) Stepped control and 3-step pushbuttons for hoist functions should be provided when infinitely variable control using a pendant station is provided.
- (g) The maximum voltage in pendant pushbutton stations shall be 150 Volts AC or 300 volts DC.
- (h) An independent festoon system dedicated to the pushbutton station is recommended to be used. Refer to section 2-5.20 for festoon system requirements.

2-5.16.2 **Cab Control Stations.**

- (a) Cab master switches, pushbuttons and lighted indicators may be console or armchair mounted.
- (b) The operator's chair shall:
 1. be adjustable forward and backward and
 2. rotate as necessary to provide access to the controls and operator visibility of the load.

2-5.16.3 Master Switches.

- (a) Master switch operating handles should be spring returned to neutral with an off position detent. If a master switch is not spring returned to the off position, a dead-man switch shall be provided on each controller; at least one dead-man switch shall be continually hand activated in order to operate all crane motions. Master switch operating handles shall be in the OFF position before any initial crane function can begin.
- (b) The movement of the travel master switch handles should be in the same general direction as the movement of the load.

2-5.16.4 Radio Controls.

- (a) Wireless radio control systems shall be designed and installed in accordance with ANSI ECMA 15, CMAA #70, Section 5-15, and NEMA ICS 8, Part 9.
- (b) Transmitter signals shall be digitally pulse encoded with error detection.
- (c) Radio controller units shall maintain a continuous status signal to the associated receiver during operation.
- (d) A contact or output relay monitoring board, or some other form of command confirmation shall be provided with the crane radio system receiver.
- (e) If more than one crane in the building is to be operated by radio controls, ensure that there will be no interference between the systems. Additionally, where multiple remotely controlled cranes operate in close proximity to each other, the systems shall mitigate the possibility of inadvertent crane operation by use of the wrong remote unit.
- (f) The system frequency for radio control systems shall be within the unlicensed FCC Part 15 range unless there are specific facility interference issues or licensing requirements.
- (g) For unlicensed radio control systems, a Form DD 1494 shall be submitted for information. For licensed radio control systems, Form DD1494 shall be approved prior to purchasing equipment and obtaining a specific frequency from the frequency coordinator. Forms may be submitted via the Equipment Location Certification Information Database (EL CID) on-line system in lieu of submitting the DD 1494 form.

- (h) An identical backup transmitter should be procured.
- (i) Only one transmitter at a time shall be able to control the crane.
- (j) Radio transmitters are required to include the following:
 - 1. A key operated battery power switch.
 - 2. An indication of battery power.
 - 3. An indication of transmitting status.
- (k) Battery assemblies should be of the rechargeable type.
- (l) Not less than two sets of batteries should be provided for each transmitter.
- (m) There shall be no significant loss in the system's efficiency and function at the end of eight hours of continuous battery use.
- (n) Consideration should be given to the use of signal limiting devices to limit the distance an operator can be away from the crane and operate the radio controller.

2-5.17

Operator Indicator Lights and Warning Devices.

- (a) A white light to indicate that power is available on the load side of the crane disconnect shall be viewable from the operator's station.
- (b) A blue light to indicate that the main contactor is energized shall be viewable from the operator's station.
- (c) A red motor over-temperature pilot light is required if a motor over-temperature device is specified.
- (d) When a crane is equipped with a slow speed or micro-speed mode, a yellow or amber light to indicate slow speed or micro-speed mode should be provided and should be viewable from the operator's station.
- (e) When a selector switch is provided on the operator's station to allow for operating multiple functions (e.g. two trolleys, two hoists, two bridges operated independently or in tandem) from the same set of controls, a green light viewable from the operator's station shall be provided to indicate the function that is currently being controlled. If the controller allows for tandem operations, the green

light for both tandem functions shall be illuminated when in tandem mode.

- (f) An audible or visual warning device shall be provided for all cranes; except for pendant controlled cranes where the ability of the operator to warn persons in the path of the load is not impaired. The warning device should be a horn or siren operated from a push button at the operator's station.
- (g) On portal and floating cranes which are variably-rated at capacities less than their straight-line rating beyond a certain main hoist hook radius, a flashing yellow pilot light shall be provided in the cab to indicate that the hook is beyond the maximum radius for its straight-line rating.
- (h) On cranes utilizing spud locks, boom pawls, or other such remote stowage devices that are operable from the operator's station; indicator lights shall be provided to indicate both engagement and disengagement of these devices.
- (i) LED type lights should be used for all indicator lights.
- (j) Indicator lights should be installed on the underside of indoor cranes (mounted on bridge, control panel, separate panel, etc.) where they are visible from the operating position. Indicator lights should only be installed on remote controllers and pendant controllers when glare or other circumstances make indicator lights mounted on the crane difficult to see. In lieu of indicator lights, LCD or similar type displays may be used on remote and pendant controllers.

2-5.18 Transformers.

- (a) AC control circuits shall be fed from a single phase, air cooled, double wound transformer with a grounded metal screen between the primary and secondary windings of the transformer.
- (b) Refer to section 2-5.19.5 for overcurrent protection requirements for transformers.
- (c) Refer to section 2-5.22 for application requirements of isolation transformers.

2-5.19 Protective and Disconnecting Devices.

- (a) Overcurrent protection is shall be provided, and is addressed in NEC Article 610 Part V. Both equipment and conductors shall be protected.

- (b) Protection shall be provided from short-circuits, ground-faults, and motor overloads
- (c) Selective coordination of overcurrent devices is not required. However, each load side overcurrent device should be sized smaller than the line side overcurrent device that supply it.
- (d) Disconnecting means shall be provided, and are addressed in NEC Article 610 Part IV.

2-5.19.1 **Crane Feeder Protection**

- (a) Feeders to motor branch circuits, including runway supply conductors and main contact conductors, shall be protected either by an overcurrent device that shall comply with one of the following:
 - 1. Not be greater than the largest rating or setting of any branch circuit protective device plus the sum of the nameplate rating of all other loads per NEC Article 610.41(A).
 - 2. Not be greater than the ampacity of the feeder conductors after all ampacity correction factors have been applied.
- (b) If multiple cranes are on a common conductor system, demand factors in NEC Table 610.14(E), may be used to determine crane feeder protection.

2-5.19.2 **Motor Branch Short-Circuit and Ground-Fault Protection**

- (a) NEC Article 610.42(A) requires motor branch circuits to be protected from short-circuits and ground-faults in accordance with NEC Table 430.52. Protection should be provided by inverse time circuit breakers.
- (b) Motor branch circuit protection may be increased to the next higher size device for values calculated using NEC Table 430.52. This allows for accommodation of standard ratings of protective devices and motors which have excessive starting currents. The standard ratings for fuses and circuit breakers are listed in NEC Article 240.6
- (c) Instantaneous trip circuit breakers are not acceptable to provide short circuit and ground fault protection.
- (d) Motor full load current from NEC Article 430, Part XIV (Tables) shall be used to calculate overcurrent and ground fault protective device requirements, rather than the nameplate amperes of a specific motor so that the motor can be replaced with another motor, having

the same horsepower rating, without necessitating the replacement of overcurrent protective devices; this is addressed in NEC Article 430.6.

- (e) Circuit breakers used for motor branch protection shall be capable of being locked out. Means for locking should remain in place with or without the lock installed.
- (f) Conductors for brake coils shall be protected by a fuse or other protective device. The device shall be chosen to protect the brake circuit conductors from ground-faults or short-circuits.

2-5.19.3 **Motor Overload Protection.**

- (a) Motor and branch circuit overload protection shall be provided in one of the following ways:
 - 1. For all microprocessor controlled cranes (AC and DC), automatic resetting type thermal sensing devices that are sensitive to motor temperature embedded in the motor windings.
 - 2. Overload relay elements in each ungrounded circuit conductor are permitted for non-computer controlled cranes.
- (b) Overload relays shall be selected to trip at no more than 150 percent of motor nameplate amperes.
- (c) Activation of an integral motor over-temperature device shall de-energize the associated function as follows: Hoist (hoisting direction only), Trolley and Bridge (travel motion in either direction). The Navy Crane Center also recommends activation of a red fault light.
- (d) For cranes with maintained controllers (non-spring returned to neutral), a safety circuit shall be included which requires all controllers to be returned to neutral before any motion can continue after a motor overload device has been activated.
- (e) DC motor overload protection shall be in accordance with NEMA ICS 8.
- (f) Electronic relays may be utilized in a variable voltage DC control system with Navy Crane Center approval.

2-5.19.4 **Control Circuit Protection.** Control circuit conductors are required in NEC Article 610.53 to have overcurrent protection; however, they are considered

protected by an overcurrent device having a rating not in excess of 300 percent of the conductors' ampacity.

2-5.19.5 Transformer Protection.

- (a) Overcurrent protection of transformers shall meet the requirements of NEC Table 450.3(B).
- (b) NEC Article 430.72(C)(4) allows for an overcurrent device rated at 500 percent of the rated primary current when the rated primary current is less than 2 amps..
- (c) NEC Article 240.4(F) considers the secondary conductors of a single-phase transformer having a "2-wire" (single voltage) secondary to be protected if the primary side of the transformer is protected in accordance with NEC Article 450.3(B) and the overcurrent protection device's rating does not exceed the value determined by multiplying the secondary conductor ampacity by the secondary to primary transformer voltage ratio.

2-5.19.6 Ancillary Equipment Circuit Protection.

- (a) Overcurrent protection of circuits supplying ancillary equipment shall be selected based upon the applicable requirements of the NEC for the specific equipment.
- (b) Overcurrent protection devices supplying receptacles shall be protected by a device with a minimum rating of 15 amps.
- (c) Conductors for ancillary circuits shall be protected by an overcurrent protection device rated less than the conductor ampacity unless otherwise permitted by the NEC.

2-5.19.7 Crane Disconnecting Means.

- (a) On bridge cranes, gantry cranes, wall cranes, monorails, etc., the disconnecting means shall be sized for simultaneous operation of the largest hoist drive and all travel drives.
- (b) Disconnecting means for cranes shall be in accordance with NEC Article 610.32.
- (c) The crane disconnecting means should be a lever arm type switch located in a separate enclosure, such that when the disconnecting means is secured, there are no energized conductors in any control panels.

- (d) Disconnecting means used for isolating the crane from the power supply shall be capable of being locked out. Means for locking shall remain in place with or without the lock installed.
- (e) If the disconnecting means for a crane does not remove power to ancillary circuits on the crane a warning shall be placed on both the crane disconnect and the ancillary equipment disconnecting means.

2-5.20 **Electrification.**

- (a) Crane supply conductors shall be sized for simultaneous operation of bridge, trolley, hoist drives and any continuous loads.
- (b) Continuous loads such as utility, heating, lighting, and air conditioning shall be multiplied by 2.25 to determine ampacity in order to permit application of NEC Table 610.14(A) for crane supply conductors. Or, as an alternative, NEC Article 310 may be used.
- (c) Refer to section 2-5.21 for electrification system grounding requirements.
- (d) Refer to section 2-5.11 for voltage drop requirements of runway systems.
- (e) Environmental conditions such as ice buildup, UV exposure, or condensation shall be considered when selecting electrification systems.

2-5.20.1 **Rigid Conductor Bar Systems.**

- (a) Rigid conductor bar systems shall be the manufacturer's standard catalog components and may be made out of copper, aluminum, steel, stainless steel, galvanized steel or similar material.
- (b) Rigid conductor systems should be of the discreet rail type.
- (c) Rigid conductor bar systems should be of the safety enclosed type for personnel safety.
- (d) Two collector shoes for each conductor bar shall be used with rigid conductor systems. Each collector shoe shall be rated for its branch circuit current or higher so as to provide redundancy.
- (e) The insulating cover for the ground conductor is recommended to be green.

- (f) For under running cranes with trolleys that transfer to another bridge or spur track, interlocking conductors are required.
- (g) If it is possible for the hook block or wire rope to swing into the rigid conductor bar system, a guard shall be installed to prevent contact.

2-5.20.2 **Festooned Conductor Systems and Cable Carrier Systems.**

- (a) Cable loops for festoon systems shall not extend low enough to come into contact with any obstructions.
- (b) Twenty percent of the control conductors included in a new festoon conductor system or cable carrier system should be spares.
- (c) Conductors used in a festooned or cable carrier system shall be designed to be used in these types of electrification systems.

2-5.20.3 **Collector Ring Assemblies.**

- (a) Spare rings of each size of collector ring shall be provided on new cranes: three for 3-phase AC circuit and two for single phase AC circuit and DC circuit applications.
- (b) The collector rings on portal and floating cranes shall be fabricated from a copper alloy; silver plated rings are required to be utilized in wired communication circuits.
- (c) Collector ring assemblies shall be selected based upon their non-rotating, continuous duty current rating.
- (d) Collector ring assemblies shall be mounted in such a location and method that they are readily accessible for maintenance and inspection. Brushes and brush holders must be available for inspection and individual brush replacement without disassembly.

2-5.21 **Grounding/Bonding/Lightning Protection.**

- (a) A copper equipment grounding conductor, sized in accordance with NEC Table 250.122, shall be routed with all ungrounded conductors.
- (b) Only one equipment grounding conductor shall be run in each conduit and be the largest size required for any circuit routed in that conduit.
- (c) A dedicated ground conductor shall be provided in the bridge and runway electrification systems. Grounding is not permitted through the bridge or trolley wheels.

- (d) All exposed non-current carrying metal parts of cranes (including pendant controllers), shall be bonded either by mechanical connections or bonding jumpers to create a uniform ground fault current path.
- (e) Panels should have their doors, back sheets, and panel boards bonded together with flexible bonding straps. Bonding straps and equipment grounding conductors shall be connected to engineered ground points, have all paint removed from their termination points, or have tooth lockwashers (star lockwashers) installed, to insure proper grounding of the equipment.
- (f) When specified, a copper ring/collector assembly shall be provided on cranes to ground each hoist drum. The ring shall be electrically bonded to the drum. The collector shall be stationary and connected to the equipment grounding conductor by means of a No. 8 AWG copper conductor.
- (g) For lightning protection on portal or floating cranes, bonding conductors are required to be provided across all gudgeons and the boom and strut hinge pins; the minimum size of these conductors is to be 2/0 AWG. The upper works shall be electrically bonded to the portal base utilizing 2/0 AWG conductors and a collector ring having a minimum cross-sectional area of 70 square millimeters
- (h) For lightning protection on outdoor bridge and gantry cranes and hoists, the ground conductor in both the bridge electrification system and the runway electrification system shall be sized to be 2/0 AWG (minimum) for cable reel systems, festoon systems, and cable carrier systems or have a minimum cross-sectional area of 70 square millimeters for conductor bar.

2-5.22

Transients and Harmonics Protection.

- (a) Transient protection shall be provided for electronic drive controllers and is typically provided internal to the controller on electronic drive controllers. If transient protection is not provided by the electronic drive controller, a metal oxide varistor (MOV) connected line-to-ground close to the line terminals of the controller shall be provided.
- (b) For motors less than 50 horsepower harmonics protection shall be provided for electronic drive controllers and shall consist of a reactor connected in series with each controller's line (input) terminal or a device specified by the drive manufacturer.

- (c) With motors of 50 horsepower or greater, harmonics protection for electronic drive controllers shall be provided and shall be an isolation transformer.
- (d) Electronic drive controllers shall be provided to meet IEEE STD 519 current distortion limits at the point of common coupling where required/enforced by the local utility.
- (e) The electronic drive controller shall not interfere with the proper operation of other drives and electronic equipment on the same crane.
- (f) For motor branch circuit conductor lengths exceeding 100 feet, a reactor or a device specified by the drive and/or motor manufacturer shall be connected in series with the controller load (output) terminals to provide standing wave protection.
- (g) Refer to section 2-5.7 for transient protection requirements for contactors and relays used with electronic drive controllers.

2-5.23

Illumination.

- (a) In mercury exclusion areas fluorescent and high intensity discharge (HID) lamps (which contain elemental mercury) shall be installed within sealed lenses or refractors which serve as a second means of containment for the mercury.
- (b) If metal halide fixtures are to be used, type O or S lamps shall be used.
- (c) Refer to section 2-1.11.1.14 for emergency illumination requirements.

2-5.23.1

Crane Passageways and Spaces.

- (a) Compact fluorescent or LED lamps should be used to illuminate crane passageways and spaces.
- (b) On outdoor cranes, exterior footwalks, ladders, and stairs shall be illuminated to 5 foot-candles.
- (c) For stairways and ladders where illumination is required, switches shall be provided at both the top and bottom of the ladder or stairway.
- (d) Machinery houses shall be illuminated to 40 foot-candles at a work plane 3 feet above the floor with a switch located at each entrance.

- (e) The operator's cab should be provided with two lighting systems, one providing white light and the other red light for "night vision", where applicable.
- (f) On cranes where operator access/egress will be required outside at night, access lighting shall be provided when the crane's electrical system is not energized. This system should be supplied from the diesel engine starting batteries or other source of power available when the crane is not energized.
- (g) When batteries are used to provide access lighting, timer type switches should be used to limit the length of time current is being drawn from the batteries.

2-5.23.2 **Flood Lights and Spot Lights.**

- (a) LED, Metal halide, or tungsten halogen (quartz) lamps should be used in floodlights and spotlights.
- (b) On portal, container, and floating cranes, floodlights shall be mounted along the boom to illuminate the work area beneath it.
- (c) Mounting brackets for the floodlights shall be designed to permit the floodlights to hang plumb at any boom angle.
- (d) On portal, container, and floating cranes, floodlights shall be mounted around the portal base or rotate tube to illuminate the area about the crane.
- (e) Floodlights for the work area should be switched from each operator's station.
- (f) Spotlights, trainable from within the operator's cab, shall be provided on portal, container, and floating cranes.
- (g) The floor area beneath a bridge crane shall be illuminated to 40 foot-candles at a work plane 3 feet above the floor.
- (h) Floodlights on indoor cranes should be spaced to match the building's lighting fixture arrangement so as to compensate for the shadow cast by the crane.
- (i) Floodlights should be designed to be serviceable from walkways on the crane.
- (j) Floodlights shall be equipped with safety cables to prevent the fixture from falling if dropped while being serviced.

2-5.23.3 **Aircraft Warning Lights.**

- (a) If the highest location on a crane is more than 200 feet above the ground, aircraft warning lights shall be installed.
- (b) If aircraft warning lights are installed on the tip of the boom, the control circuit for the warning lights shall be designed to ensure that the aircraft warning lights are energized when the boom tip is 200 feet or more above the ground and de-energized when it is below 200 feet above the ground.
- (c) Local civil aviation authorities should be consulted as they may have more stringent rules if an airfield is located nearby.
- (d) Aircraft warning lights shall be fed from a source of power (such as hotel power or solar rechargeable batteries) that remains energized when the crane is de-energized.

2-5.24 **Insulated Links.**

- (a) Installation of these links should be considered for outdoor cranes (including mobile and articulating cranes) that handle electrically sensitive loads and cranes that operate near radio frequency (RF) generating sources. NAVSEA OP-5 governs the use of insulated links while lifting ordnance.
- (b) Insulated links should be selected on the basis of their load rating, rated operating voltage, rated leakage current, and expected non-crane radiated electromagnetic frequencies. These links are not lightning proof, and electrical ratings of some designs are degraded when wet.
- (c) A dedicated gauge for verifying the original length of the link should be procured with each link to ensure that none of the link components have yielded in service. Alternatively, tram points may be utilized as outlined in NAVFAC P-307.
- (d) Refer to section 2-9.9 for requirements for insulated links used as rigging equipment.

2-5.25 **Shore Power.**

- (a) For AC shore power, two types of connections are required on portal, floating, and container cranes:
 - 1. one sized to supply hotel power to all of the ancillary loads on the crane; and

2. one sized to provide sufficient power for full crane operation.

- (b) It is recommended to have similar connections for DC shore power, when it is available.
- (c) Interlocks shall be provided to prevent simultaneous power to the crane from more than one source.

2-5.26 **Attached Safety Systems and Devices.**

2-5.26.1 **Capacity Overload Protection.**

- (a) Capacity overload protection which prevents further hoisting of a load shall be provided on all cranes.
- (b) Capacity overload protection shall be set at or less than the crane's test load.
- (c) A keyed override or other means of bypass shall be provided on each crane to disable the capacity overload protective device when performing a load test.
- (d) When a microprocessor drive is used for the hoist function of a crane, and the drive has torque limiting functionality that is separate from the capacity overload protective device, the torque limiting functionality shall be turned on and set greater than the test load. This will prevent gross overloads when the capacity overload protective device is being bypassed. This torque limiting value should initially be set at approximately 150 percent of the motor torque (amperage) necessary to hoist 100 percent load. It should be adjusted up only to avoid nuisance trips and adjusted down if possible while still avoiding nuisance trips.

2-5.26.2 **Load Indicating or Limiting Devices (Dynamometers, Load Cells, Crane Scales, Load Moment Indicators (LMI), Rated Capacity Indicators (RCI), Rated Capacity Limiters (RCL), Load Indicating Devices (LID), etc.).**

- (a) LMIs, RCIs, RCLs, or LIDs, as appropriate, are required on new category 1 and 4 cranes.
- (b) The weight of the load under the hook shall be displayed at the operator's station when load indicating devices (LIDs) are used. Remote indications visible at other locations should be incorporated at the activity's option.

- (c) The minimum design factors for steel and aluminum load bearing components shall be 5 and 7 respectively, based on the material ultimate tensile strength respectively.
- (d) Some commercially purchased LIDs do not meet the minimum design factors specified in section 2-5.27.1(c). These devices may only be used at a reduced maximum rated load which corresponds to the design factors specified in section 2-5.27.1(c). These devices shall be marked or tagged to indicate the reduced maximum rated load.
- (e) The hardness of steel load bearing components shall not exceed 40 HRC. Precipitation hardened stainless steel (e.g. PH17-4) load bearing elements shall be age hardened at a minimum temperature of 1025 degrees Fahrenheit.
- (f) LIDs shall be designed to not inadvertently disassemble (e.g., due to rotation of assemblies below the device while assemblies above the device do not rotate).
- (g) Load indicating and limiting devices integrated into cranes shall comply with the minimum performance criteria of SAE J159.

2-5.26.3 **LMI, RCI, and RCL Systems.**

- (a) LMIs or RCLs are required on new mobile cranes.
- (b) LMI, RCI, and RCL systems shall comply with the minimum performance criteria of SAE J159.

2-5.26.4 **Anti-Two-Block (A2B) Devices.**

- (a) A2B devices that prevent two-blocking are required on mobile cranes.
- (b) A2B devices shall comply with the minimum performance criteria of SAE J1305.
- (c) Some older mobile cranes are not equipped with an A2B. When they are to be retrofitted with them, they shall be retrofitted with an A2B that prevents two-blocking (not just an A2B warning device) and a Crane Alteration Request shall be submitted to the Navy Crane Center for approval.

2-5.26.5 **Wind Speed Indicating Systems.**

- (a) Wind speed indicating devices shall be provided on new portal, floating, container, and outdoor bridge and gantry cranes. A single wind speed indicating device that monitors multiple locations may be used for more than one crane when approved by the Navy Crane Center. On mobile cranes, they are standard equipment on some models and optional equipment on others; when available, they are a recommended option.
- (b) Wind speed indicating devices shall give a visible and audible alarm to the crane operator at a predetermined wind speed.
- (c) A transmitter shall be mounted on the highest unobstructed location.
- (d) The transmitter should be fitted with a heater to eliminate freezing where practical.

2-5.27 **Anti-Condensation Heaters for Motors, Generators, Control Equipment and Collector Rings.**

- (a) Anti-condensation heaters should be installed in the generators, motors, collector rings, and control panels when required by the component OEM or where condensation problems are known to exist.
- (b) Heaters should remain energized when the mainline contactor is de-energized. If hotel power is utilized, they should be fed from a separate panel dedicated to equipment heater and battery charger circuits.

2-6 **FIRE PROTECTION SYSTEMS.**

2-6.1 **Operator's Cabs and Walk-In Spaces.**

- (a) Operator's cabs and walk-in spaces on cranes that contain potential sources of fire shall be equipped with fire protection equipment that complies with current National Fire Protection Association (NFPA) standards. Additionally, a 10-pound 4-A:60-B:C dry chemical portable fire extinguisher shall be located in every operator's cab.
- (b) Fire extinguishers shall comply with NFPA 10. Fire extinguishing agents shall be approved by the Environmental Protection Agency (EPA)

2-6.2 **Diesel Engine Compartments.** Crane compartments that contain diesel engines (either main or auxiliary) or fuel tanks shall have a fixed fire-extinguishing system.

2-6.3 **Extinguishing Systems.**

- (a) When the compartment floor is higher than the reach of the local aerial ladder fire apparatus, the extinguishing system shall be automatically actuated.
- (b) When the compartment floor is lower than the reach of the local aerial ladder fire apparatus, the extinguishing system may be either automatically or manually actuated.
- (c) Automatically actuated extinguishing systems shall be provided with back-up manual actuation.
- (d) The extinguishing systems shall comply with NFPA 12 or NFPA 2001.
- (e) Extinguishing system piping shall be suitably marked to indicate "FIRE EXTINGUISHING SYSTEM", the compartment(s) that it protects, and normal direction of flow.
- (f) System piping is to be painted a bright red color.

2-6.3.1 **Extinguishing Agent.**

- (a) The extinguishing agent discharge pipe shall include a shut-off valve that is to be locked in the open position, except when the diesel engine, electric generator, or the extinguishing system is undergoing maintenance. It shall be lockable in the shut position to allow securing the system during maintenance.
- (b) In cases where a single system protects more than one compartment, the quantity of extinguishing agent need not be more than that required for the largest compartment, provided that the system controls allow the system to flood only one compartment at a time.
- (c) The extinguishing agent containers shall be mounted outside the protected compartments in safe, readily accessible locations.
- (d) The containers shall be marked with normal weight or volume of agent, and provided with a reliable means of checking the quantity of agent in them.

2-6.3.2 **Manual Actuation Stations.**

- (a) A manual actuation station shall be located outside each protected compartment adjacent to the primary entrance/exit.
- (b) Manual actuation controls shall be guarded, double-action type.
- (c) Each station shall be clearly labeled as to its function and which protected compartment(s) it will flood.

2-6.3.3 **Warning Signs.** Warning signs shall be provided at each entrance to each protected compartment indicating that the compartment is protected by a total-flooding fire-extinguishing system and shall be promptly evacuated when the alarm sounds.

2-6.3.4 **Fire Alarm Systems.**

- (a) An automatically actuated audible alarm system shall be provided for the fire alarm system.
- (b) To the maximum extent practicable, the system shall comply with NFPA 72.
- (c) Upon detection of fire, the alarm system shall annunciate audibly and visually in the operator's cab.
- (d) Upon actuation of the extinguishing system (either automatic or manual), but prior to agent discharge into the protected space, the alarm system shall:
 - 1. provide warning of the impending release of the fire-extinguishing agent,
 - 2. shut down all ventilation fans
 - 3. close all openings which admit air into, or would allow the fire-extinguishing agent to escape out of, the protected compartment.
- (e) The diesel engine, if running, shall not be shut down by the alarm system.
- (f) After a minimum 20 to 30-second pre-discharge alarm time, extinguishing agent shall be released into the protected compartment.
- (g) The alarm system may be powered electrically or pneumatically.

- (h) The ambient design temperature for the entire system shall be taken as 104-degrees F.

2-6.4 **Machinery Houses.**

- (a) Machinery houses shall contain two 10 pound clean agent ABC portable fire extinguishers. One shall be located near the primary entrance. The second shall be centrally located to the electrical drive control equipment.
- (b) Fire extinguishers shall comply with NFPA 10.

2-6.5 **Floating Crane Barges.**

- (a) Fire protection systems of floating crane barges shall comply with the requirements of NFPA 301, Code for Safety to Life from Merchant Vessels.
- (b) For purposes of application of NFPA 301, floating crane barges shall be considered "Towing Vessels 12 m (39.4 ft) or More in Length and Greater Than 375 kW (500 hp)".
- (c) Floating crane barges shall have fixed raw water fire-fighting and deck wash-down systems to protect all deck enclosures, and below-deck crew quarters and machinery compartments.
- (d) Above-deck hydrants and water pipes shall be located or protected so that they are not vulnerable to being damaged by cargo handling, but are readily accessible for connection of fire hoses.
- (e) Fire main materials shall be selected for resistance to heat damage or be adequately shielded in accordance with NFPA 301.
- (f) On floating crane barges operated in salt water, fire main materials shall also be resistant to corrosion.
- (g) On floating crane barges operated in cold climates, fire mains and hydrants shall be protected against freezing.
- (h) The fire fighting system shall be capable of discharging water through hose lines from the two hydraulically most remote hydrants simultaneously at minimum of 80 gpm at each nozzle at the nozzle pressure recommended by the nozzle manufacturer, but not less than 75 psig at the nozzle.
- (i) The nozzles shall be variable-pattern straight/fog type.

- (j) Minimum fire hose size is to be 1-1/2 inches nominal diameter.
- (k) Hose coupling threads shall be NPSH to match U.S. Navy surface vessel fire hoses.
- (l) The fire pump(s) shall be a permanently fixed installation with a minimum pumping capacity of 250 gpm. (Use of a portable pump to meet the fire flow requirements is not an acceptable alternative.)

2-7 **SUPPLEMENTAL REQUIREMENTS.** Cranes operating in non-routine environments or unique, dedicated service shall include the following additional features and characteristics in addition to those described in the preceding sections of this instruction. In many cases the prescribed crane classifications correspond to more severe commercial service than the actual operational environment of these cranes, but these classifications are warranted by the cranes' inherent higher level of reliability and robustness desired for critical applications.

2-7.1 **Special Purpose Service (SPS).** (Applicability includes commercial components)

Cranes in "special purpose service" (SPS) support various lifting operations associated with the servicing of nuclear reactors and related components aboard vessels and at shore facilities. Fail safe design methodologies, additional factors of safety and design for duty cycle in excess of expectations are required to ensure loss of control of lifted loads does not occur. These cranes are defined in and shall comply with all applicable requirements of NAVSEA 0989-030-7000, Lifting Standard. In addition to all previous design requirements, the following design features are mandatory for new and overhauled SPS cranes. Any deviations shall be approved by the Navy Crane Center:

- (a) Top running bridge cranes shall be CMAA #70, Class D or higher. Mean Effective Load Factors shall be estimated to ensure a higher class than class D is not required.
- (b) Under running cranes shall be CMAA #74, Class D; with patented track bridge girders per MMA MH27.1. Crane runways for under running end trucks shall also be patented track per MMA MH27.1. Standard structural shapes may be allowed with Navy Crane Center approval.
- (c) Standard commercial hoist/trolley units (package hoists) shall comply with all SPS requirements in this Sections and be ASME HST class H4 or higher. Mean Effective Load Factors shall be estimated to ensure a higher class than H4 is not required. If package hoists are used, they are required to meet ASME HST-1 (Electric Chain Hoists), HST-2 (Manual Chain Hoists), HST-3 (Manual Lever Hoists), HST-4 (Electric Wire Rope Hoists) Duty

Class H4, HST-5 (Pneumatic Chain Hoists) Duty Class A5 or HST-6 (Pneumatic Wire Rope Hoists) Duty Class A5.

- (d) Top running end trucks shall be welded plate box-sections with diaphragms between the wheel pockets.
- (e) For built up hoists, structural members, in close proximity to the wire rope drum flanges and designed specifically for the anticipated loads in case of wire rope drum failure, shall provide support for the wire rope drum in case of shaft failure. The wire rope drum supports shall maintain drum gear tooth engagement with the drive pinion (if applicable) and allow for engagement of the drum brake.
- (f) Hoist reeving systems shall be double reeved with left lay and right lay wire ropes equalized by an equalizer bar. The wire rope design factor for running rope shall be 6 or higher. Single reeved systems and systems using an equalizer sheave are allowed provided the design factor is 10 or higher.
- (g) The wire rope design factor for standing rope shall be 8. If the standing rope utilizes two or more parts and an equalizer bar for each section (boom pendant), the design factor may be 5.
- (h) The hoist shaft fatigue design factor shall be 2.0 or greater for custom shafting.
- (i) Wire rope drum and sheave groove depths shall be 0.438 and 1.150 times the wire rope diameter as a minimum, respectively.
- (j) Hoists of bridge, under running, cantilever, gantry, and semi-gantry cranes shall have one of their two spring-set hoist brakes act directly on the wire rope drum, or act independently of the primary hoist drive train as described in paragraph 2-7.1(l). A mechanical load brake may be substituted for the electro-mechanical brake not acting on the wire rope drum.
- (k) Hoists of portal and floating cranes shall be equipped with three spring-set brakes, each with a minimum rating of 130 percent of the rated load hoisting torque. One of these brakes (or sets of brakes) shall act directly on the wire rope drum. The brake acting on the wire rope drum shall function as described in paragraph 2-7.1(l), but shall not set when the controller is returned to neutral.
- (l) Hoists shall be equipped with a brake that shall act to stop and hold the wire rope drum through a torque path separate from the primary brake, either directly on the wire rope drum, or act independently of the primary hoist drive train. Brakes acting directly on the wire rope drum shall be either the caliper disc or band type. Single or

multiple caliper disc brakes shall be applied to one or two discs bolted to the drum. Band brakes shall be applied to the drum barrel. Where there is a single path of torque transfer between the hoist motor and the wire rope drum, a broken shaft detection system (BSDS), or equivalent system, shall be provided that upon detecting a loss of hoist drive train continuity shall immediately stop and hold the wire rope drum. The brake acting to stop and hold the wire rope drum shall set immediately in the event of loss of power or crane shutdown. See also paragraph 2-4.2.1(m)

- (m) When transferrable trolleys (carriers) are utilized with under running cranes, the following additional features shall be provided:
1. Limit switches shall be used to indicate when two bridge structures are properly aligned for trolley transfer and shall prevent activation of the associated interlock system unless the bridges are properly aligned.
 2. Limit switches shall prevent disengaging the bridge interlock when the trolley position spans the bridge junction; and prevent bridge movement if the interlock is not disengaged.
 3. Limit switches shall activate an indication system that shows the operator the status of the interlock system including: when the bridges are not aligned, when the bridges are aligned, when the interlock is engaged, and when the interlock is not engaged.
 4. Limit switches shall slow the trolley to 10 percent of its rated speed as it approaches the trolley end stops and transitions through the bridge-to-bridge junction.
 5. The trolley end stops shall be mechanically configured such that they can be disengaged only when a bridge is aligned to a mating bridge structure.
 6. During the bridge-to-bridge transfer process with rated load, the lower bridge flange stresses shall be in accordance with the applicable standard for the entire length of the flange.
- (n) Crane hoist drives shall incorporate an overspeed detection system such that, when an overspeed event is detected, it immediately sets the hoist brakes and de-energizes or dynamically brakes the hoist motor.
- (o) Hoists that work over spent fuel water pools shall be equipped with a second lower limit switch wired independent of the directional contactors and of the primary limit switch, such that its activation

will result in the removal of power from the motor and set the brakes via a hoist line contactor or mainline contactor. A three-position spring-returned keyed bypass switch should be included in the design. The keyswitch shall allow for bypassing of the primary lower limit switch to allow for testing of the secondary lower limit switch and shall allow resetting of the secondary lower limit switch prior to resuming operation. During resetting of the secondary lower limit, the hoist shall operate in the raising direction only.

- (p) Cranes shall be designed to allow for manually lowering the load in the event of emergent conditions. This may require repositioning of the bridge, trolley, boom, or crane as necessary.
- (q) A mis-spool limit switch shall be used to detect improper spooling of the hoist rope onto the wire rope drum. The switch shall prevent further hoisting but shall allow lowering.
- (r) An unbalanced load limit switch shall be provided to detect potential unequal loading of the wire ropes on double reeved hoists with equalizer bars. Upon detection of an unbalanced load the limit switch shall prevent further hoist motion. The switch shall automatically clear once the load is balanced, otherwise, further hoist motion shall require the use of a keyed bypass switch to override the limit switch.
- (s) Cranes equipped with wireless controls have additional requirements beyond those of paragraph 2-5.25:
 - 1. The crane startup may be made by an infrared (IR) link.
 - 2. The cranes shall be equipped with a backup means of wired control. The backup means of control shall be accessible and useable regardless of bridge or trolley location in the facility.
 - 3. The part of the wireless control that performs the stop function shall be designed to Category 3 or higher for safety performance as defined in clause 6.2.4 of EN 954-1:1996. (It is noted that in ANSI ECMA 15 this requirement is a 'should'.)
 - 4. Where wireless controls are used on cranes with transferable trolleys, the bridge and any trolley mounted on that bridge shall electronically interlock with the remote unit such that the remote unit will not operate any other bridge. The bridge must be capable of operation without a trolley.
- (t) Gray cast iron load bearing parts shall not be utilized. Gray cast iron load controlling parts may be allowed with Navy Crane Center approval. Drive components of hoists—those that transmit the

driving torque, braking torque, and their supports/housings including the wire rope drum and bearing housings/supports— shall be steel. Exceptions are permitted for brake wheels and discs, which may be ductile or malleable cast iron; and speed reducer and electric motor housings, which may be ductile or malleable cast iron or aluminum. These ductile and malleable cast iron and cast aluminum components shall have a minimum elongation of 5 percent in 2.00 inches. Package hoist/trolley units shall be equipped with forged steel wheels.

- (u) Mobile cranes require minimal modifications from their standard commercial configuration other than a wire rope design factor of 10 or greater on running rope and 8 (or 5 as noted above) or greater on standing rope. (This requirement may be satisfied either by de-rating the crane or replacing the original wire rope with one of higher strength.) However, mobile crane types, models, and options should be carefully researched and selected in order to provide the most reliable and redundant safety systems available (e.g. 3rd wrap detectors, outrigger span detectors, etc.). Additionally, the Lifting Standard requires specific mobile crane testing criteria that will require applicable load charts to be downrated accordingly. Consult the applicable paragraph in the Lifting Standard on RSPC. Mobile cranes that will handle fuel require specific options or modifications and prior approval of Navy Crane Center. Free-fall capability is prohibited on SPS mobile cranes.
- (v) Trolleys and bridge end trucks of top running bridge cranes (and other cranes with such top running components) shall be analyzed for the applicable seismic forces and shall be equipped with seismic restraints. Depending on the particular crane design and seismic zone, the restraints may be required against both lateral dislodgment and lift-off. The restraints may engage the rail head or the flange of the structural rail support member. If restraints engage the rail head, an analysis showing the rail system will withstand this loading is required. The seismic analysis shall be performed using the methodology of ASME NOG-1 Section 4150 for an SSE except that the damping factor in the vertical direction for the trolley and bridge structures shall be 4 percent. The damping factor in the vertical direction of the load and load block shall be 7 percent. Under running cranes do not require seismic analysis.
- (w) Portal cranes shall be analyzed for the applicable seismic forces. In addition, the king pin for portal cranes that rotate on roller path and king pin assemblies shall be designed for the total shear load due to the horizontal seismic force.

- (x) When the specific activity area requires a high degree of cleanliness, external structural welds of indoor cranes shall be smooth (so that they will not tear a cotton cloth when scrubbed on them) to permit complete removal of any radioactive contamination that may have been accidentally released and deposited on them.
- (y) Cast steel sockets, in both outdoor and indoor installations, shall meet the following minimum values of fracture toughness. Those cast of carbon steel, shall have a minimum fracture toughness of 15 foot-pounds at 10 degrees Fahrenheit; those cast of alloy steel, 30 foot-pounds at 10 degrees Fahrenheit. The values of fracture toughness shall be determined by Charpy V-notch tests on sockets from the same lot. Sockets shall have a minimum breaking strength that is five times the manufacturer's rated safe working load. Forged steel sockets shall meet the same material requirements of RR-C-271 as shackles. Stainless steel sockets shall be forged from austenitic stainless steel meeting the requirements of ASTM A314 for material composition.
- (z) Under running trolleys shall have provisions to prevent the trolley from dropping more than one inch in case of wheel or axle failure.
- (aa) Motor rotors, armatures, and commutators of hoist motors shall be press fitted and keyed to motor shafts.
- (bb) The crane shall be designed to prevent uncontrolled lowering or dropping of the load due to operator error or incapacitation. For example, spring return pushbuttons or switches are acceptable provided that an incapacitated operator cannot activate the controls by falling onto them. Cab operated cranes shall be equipped with "dead-man" controls (other than foot operated); or alternatively, with a seat for a back-up operator
- (cc) Hoisting equipment shall be designed to guard the hoist wire rope to prevent pinching, snagging or other damage at the side of the hoist drum or between the hoist drum, crane structure, and any other adjacent equipment.
- (dd) Electric drives shall utilize motors of either the AC squirrel cage type or DC shunt wound type based upon the particular application.
- (ee) Bridge and trolley drives shall be provided with brakes or non-coasting mechanical drives.
- (ff) Cranes designated for fuel removal and discharge operations shall have the capability of being limited to a slow speed or micro-speed for those operations (e.g. keyed switch).

2-7.1.1 Captivation and Containment. Cranes used over exposed or open components or piping that requires a high degree of cleanliness shall have provisions to captivate, capture, contain, or otherwise isolate a fastener, item of hardware, fluid or other item or material that could become loose and inadvertently enter the internals of the components or piping. The degree of captivation and containment, as well as specific methods is the responsibility of the end user, however, the following additional design features are recommended as a minimum.

- (a) Load blocks should include drip pans fitted around the shank of the hook and extending outward to encompass all possible points of lubrication drips. Individual hoist components, such as speed reducers, should be equipped with drip pans unless the trolley floor is designed to contain any lubricant drips from equipment that is mounted on it. Travel drives should have drip pans or other containment provisions at all lubricated components or assemblies. (Permanently lubricated and sealed bearings are not considered drip-proof.) On portal, floating, and mobile cranes, only the outer section of the boom should be equipped with drip pans. (The outer section of the boom is typically defined as from the tip to 20 feet inward, measured horizontally from the main hoist sheave nest when the boom is at its maximum operating radius, however, site conditions may change this dimension.)
- (b) Exposed fasteners and other items of hardware that may loosen or become dislodged, should be captivated by means of applied thread locking compound, locknuts, installed lock wire, or attached chain. Items such as equipment nameplates and their fastening rivets or drive pins shall be removed and replaced with captivated threaded fasteners. The practice of tack welding structural bolts or nuts is prohibited. On bridge, under running, cantilever, gantry and semi-gantry cranes – the entire hoist, trolley, or hoist/trolley unit may require captivation. Additionally, bridge drives that pass over open reactor compartments, shall be captivated.
- (c) Devices containing elemental mercury are prohibited, unless double containment is provided for the mercury. (HID and fluorescent lamps are among such prohibited devices, but may be used if the lamps are within sealed lenses or refractors, which serve as the second means of containment for the mercury.)
- (d) Devices containing fluids, including bumpers and components of hydraulic systems, should be provided with drip pans or eliminated.
- (e) Consideration shall be given to have the original paint system removed on painted purchased components – such as motors, speed reducers, brakes, pillow blocks, and other – on bridge, under running, cantilevered, gantry, and semi-gantry cranes and the new paint system applied in accordance with the contract specifications.

2-7.2 Hazardous/Explosive Environments. (Applicability includes commercial components)

Cranes operating in hazardous environments as defined by the cognizant activity safety office shall be equipped with electrical safety features that meet NEC Article 500. The activity safety office shall identify the specific Class, Division and Group, as well as the envelope that the hazard exists, to allow proper design. Materials for mechanical components shall be chosen to minimize the potential for sparking, typically bronze, stainless steel or aluminum. In addition, selection of mechanical components, such as reducers and plain bearings, may be required considering their operating temperature.

2-7.2.1 Minimum Anti-Spark Protection. When only the load block enters the explosive area:

- (a) The load hook shall be of non-sparking material. Bronze clad hooks are not acceptable. Cast hooks are acceptable provided mechanical properties are approved by the Navy Crane Center.
- (b) Hook block sheaves or sprockets shall be of non-sparking materials (sheaves and other internal components are not required to be spark resistant if fully enclosed.)
- (c) Wire rope and load chain should be stainless steel. If the wire rope and load chain are within the explosive environment, they shall be stainless steel.
- (d) The pendent pushbutton station shall be NEMA Type 7 for Class I, hazardous environments; and NEMA Type 9 for Class II, hazardous environments, as classified by NEC.
- (e) The hook block should be non-sparking material. This may be accomplished by covering the exposed surfaces of the block with thin bronze, stainless steel, or aluminum covers attached with similar fasteners.
- (f) Hand chain on manual functions should be made of non-sparking metal. If the hand chain is within the explosive environment, it shall be non-sparking metal.

2-7.2.2 Maximum Anti-Spark Protection. When the hazardous area envelops the entire crane, in addition to protections of section 2-7.2.1:

- (a) Electrical equipment on the trolley and bridge, and runway electrification shall have anti-sparking protection in accordance with NEC Article 500.
- (b) Trolley and bridge travel wheels shall be of non-sparking materials.

- (c) Wire rope or load chain shall be of stainless steel.
- (d) Electric motors and disc brakes shall be of the totally enclosed type (shoe brakes may not be used).
- (e) Electrical enclosures shall be NEMA Type 7 for Class I, hazardous environments; and NEMA Type 9 for Class II, hazardous environments as classified by NEC.
- (f) Trolley and runway electrification shall be in the form of covered conductors, either festooned or reeled.
- (g) Upper hooks of hook suspended hoists shall be of non-sparking materials as described above.
- (h) Exposed sheaves and sprockets shall be of non-sparking materials.
- (i) Drop lug contact surfaces shall be of non-sparking materials.
- (j) Hand chain on manual functions shall be made of non-sparking material.
- (k) The bumper to end stop connection shall not be metal to metal.
- (l) An overload limiting device shall be included to prevent damage to the machinery.

2-7.3 Hot (Molten) Metal Service. (Applicability includes commercial components)

The following design features apply to cranes that handle melted metals:

- (a) Top running bridge cranes shall be CMAA #70, Class E or F.
- (b) Under running cranes shall be CMAA #74, Class D.
- (c) Standard commercial hoist/trolley units, if used, are required to meet ASME HST-1 (Electric Chain Hoists) Duty Class H4, HST-2 (Manual Chain Hoists), HST-3 (Manual Lever Hoists), HST-4 (Electric Wire Rope Hoists) Duty Class H4, HST-5 (Pneumatic Chain Hoists) Duty Class A5 or HST-6 (Pneumatic Wire Rope Hoists) Duty Class A5.
- (d) The operator's cab shall be enclosed, air conditioned, and shielded underneath the floor. The shield shall be effective in preventing injury to the operator from spill, splash, or radiant heat of the molten metal. A 1/4-inch steel plate, of the same shape as the floor and

suspended 6 inches below it to provide a fully vented space, is considered acceptable for this purpose.

- (e) Pendent pushbutton stations shall be mounted on a messenger track or an outrigger away from the hook load.
- (f) Heavy sheet metal heat shields shall be provided underneath the trolley or hoist/trolley unit, and below the load block.
- (g) The trolley frame of the hoist/trolley unit shall include safety lugs or other provisions that would limit its drop to 1.0 inch in case of wheel or axle failure.
- (h) Hoists shall be equipped with a minimum of two holding brakes regardless of the type of hoist used
- (i) Wire rope shall be selected to provide a minimum design factor of 8 and shall have an independent wire rope core. Dead end connections that are subjected to the full wire rope pull shall be zinc speltered or swaged fittings that develop the breaking strength of the wire rope.
- (j) Electrical conductors shall have high-heat insulation, selected from the types listed in NEC Table 610.14(A) for 257-degrees Fahrenheit temperature rating and de-rated for the appropriate ambient temperature.
- (k) Electrical enclosures shall be NEMA Type 3 or 12, with appropriate air conditioning based on ambient temperature requirements of the drive.
- (l) Circuit breakers shall be provided for hoist circuits; fuses for control circuits.
- (m) A horn shall be provided to provide an audible warning whenever any travel drive is energized.
- (n) An epoxy paint should be used for the hoist and trolley structural assemblies.

2-7.4 Ordnance/Explosives Handling. (Applicability includes commercial components)

Cranes handling palletized or unpackaged ammunition, missiles, torpedoes, and other types of ordnance are required to incorporate the following design features:

- (a) Top running bridge cranes shall be CMAA #70, Class D, or higher. Under running cranes shall be CMAA #74, Class D or higher; with patented track bridge girders per MMA MH27.1.
- (b) Standard commercial hoist/trolley units, if used, are required to meet ASME HST-1 (Electric Chain Hoists) Duty Class H4, HST-2 (Manual Chain Hoists), HST-3 (Manual Lever Hoists), HST-4 (Electric Wire Rope Hoists) Duty Class H4, HST-5 (Pneumatic Chain Hoists) Duty Class A5 or HST-6 (Pneumatic Wire Rope Hoists) Duty Class A5.
- (c) For custom designed (built-up) cranes, the shaft fatigue design factor shall be 1.5 or greater.
- (d) Hoists shall be equipped with a minimum of two holding brakes regardless of the type of hoist used except for manual powered hoists.
- (e) Portal, floating, container, and other cranes with the operator's cabs on the same structure as the hoist may include a foot operated hydraulic hoist brake in addition to the two electro-mechanical brakes for speed modulation. Alternatively, instead of an independent hydraulic brake, one of the electro-mechanical brakes may be equipped with an integral hydraulic system for over-riding the electrical release and applying the brake.
- (f) Gray cast iron load bearing parts are prohibited. Drive components of custom designed (built-up) hoists - those that transmit the driving torque, braking torque, and their supports/housings including the wire rope drum and bearing housings/supports— shall be steel. Exceptions are permitted for speed reducer housing and brake wheels and discs, which may be ductile or malleable cast iron; and electric motor housings, which may be ductile or malleable cast iron or cast aluminum. Ductile or malleable cast iron and cast aluminum components shall have a minimum elongation of 5 percent in 2.0 inches. Package hoist/trolley units shall be equipped with forged steel wheels.
- (g) Standard commercial hoist and hoist/trolley units, when used because of site-specific constraints, shall be selected to comply with the requirements of item (f) to the maximum practical extent. (It is considered practical to replace certain components and assemblies, such as wire ropes and load blocks, with their higher grade or custom designed counterparts.)
- (h) Cab operated cranes shall be equipped with "dead-man" controls (other than foot operated); or alternatively, with a seat for a back-up operator.

- (i) Consideration should be given to provide redundancy in the system design such as brake monitoring or supervisory controls for electronic drives.
- (j) Insulated links shall be provided to prevent the flow of electricity from radio frequency (RF) energy, from traveling through the wire ropes and metal hook to the item being lifted in accordance with NAVSEA OP 5 Volume 1, Section 10-6.1, unless the following conditions are met:
 - 1. There is no threat of a lightning strike during operations;
 - 2. There is no chance for contact with overhead power lines;
 - 3. RF emissions control is in effect regardless of the HERO classifications of the ordnance being handled.
- (k) Crane motions shall be controlled by their respective drive, i.e., no free fall mode capability.
- (l) An overload limiting device shall be included to prevent damage to the machinery.

2-7.5 **Longshoring Service.**

- (a) Variably rated cranes engaged in longshoring operations (cargo transfer as defined in NAVFAC P-307) shall be equipped with load-moment indicating devices (LMIs). This requirement applies to each variably rated hoist on a crane, and to each hoist of straight-line rated cranes that is variably rated near its extreme reach. The available choices of LMIs include those with a continuous visual display of the percentage of rated capacity for the lifted load at a particular radius as the load is maneuvered, a simple alarm (in the form of a light or buzzer) to warn the operator that the stability limit has been reached, or an automatic stop of the destabilizing outward or rotate motion.
- (b) Hoists on straight-line rated cranes shall be equipped with a load indicating device (LID). As in the case of LMIs, there are several types of LIDs available. OSHA Regulation 1917.46 contains requirements for such devices in longshoring service.
- (c) Cranes used in longshoring shall be equipped with wind speed indicating devices. In addition to indicating speed, wind direction may also be indicated. The indicating device shall also alert the operator with a visible or audible warning to a high wind condition. The warning is to be given whenever the wind reaches the speed

previously determined by the crane's designer to require special operating procedures be followed.

2-7.6 **Construction Service.** Cranes used in construction, regardless of when they were built, including mobile cranes (as defined by OSHA) shall be equipped with the following additional features:

- (a) A level indicator built into or available on the equipment (not applicable to portal crane, derricks, floating cranes, and land cranes on barges or other means of flotation).
- (b) Boom stops, except for derricks and hydraulic booms; jib stops if a jib is attached.
- (c) Foot pedal locks if the crane is equipped with foot brakes
- (d) Integral holding device/check valve on hydraulic outrigger and stabilizer jacks, boom luffing cylinders, and boom telescoping cylinders.
- (e) A boom hoist limiting device and luffing jib limiting device (for cranes with luffing jibs).
- (f) Load indicating device, rated capacity indicator, rated capacity limiter, or load moment indicator.
- (g) A horn immediately available to the operator.
- (h) An accessible fire extinguisher.

2-8 TECHNICAL DOCUMENTATION.

2-8.1 **General.** Technical documentation includes drawings, calculations and certifications needed to verify design details, assess or repair damage, and facilitate alterations or improvements. Technical documentation also includes technical manuals such as maintenance, operation, and inspection manuals.

2-8.2 **Design Responsibility.** Except as noted below, all portions of the crane design shall be performed by, or under direct supervision of, a registered professional engineer (PE) competent in the particular engineering discipline. Alternatively, the completed crane design may be reviewed and approved by a PE who is the contractor's employee or a consultant retained by the crane contractor for that purpose. In either case, the PE shall be intimately familiar with the crane contract specification and the details of the proposed crane design. Every drawing and set of calculations shall be accompanied by indication of review by a PE. Final drawings and calculations shall be stamped and signed by a PE. The stamp and signature shall be original, or otherwise comply with the applicable rules or regulations pertaining to their reproduction.

2-8.2.1 **Scope.** Crane design calculations shall, as a minimum, include analyses for each identified load combination and operating condition or configuration. The selection of standard, serially produced, components and assemblies shall be supported by their manufacturers' selection procedures. All material shall be fully identified – including their condition, mechanical properties, and allowable stress levels. Calculations shall demonstrate that the calculated stresses do not exceed the allowable values. Additionally, all alignment, torquing, and other assembly procedures shall be clearly specified on the drawings.

Drawings and calculations should be organized in a logical manner by engineering discipline and level of detail. The technical documentation should include drawings for assembly/disassembly of the crane or major components, lubrication, and jacking arrangements. Plan, elevation, and end view drawings are required to demonstrate compliance with general requirements and show clearances and hook operating envelope.

Selection of critical items, such as rotate bearings, shall include the manufacturer's certification of proper selection for the intended service and the identified load cases. Diesel engine-generator sets shall be accompanied by a torsional vibration analysis and certification that the set is free of critical torsional frequencies in the normal operating speed range. Other items which are required to comply with national, state, or local regulations (for example, compressed air storage tanks) shall be provided with appropriate certifications.

2-8.3 **Floating Cranes.** Technical documentation for the crane, including the rotate bearing and its lower structural support, shall be as described above. The barge design, including the tub, shall be reviewed and approved by the American Bureau of Shipping (ABS). The floating crane contractor is required to make arrangements with ABS for that purpose and provide the required technical documentation. The ABS review shall consider the presence and effect of the crane in the specified configurations.

Other technical data that require ABS review and approval includes the trim and stability booklet, steel certificates, welding procedures, list of ABS qualified welders and their certificates, and weld inspection and testing documentation. Following review and approval of the barge design, the contractor shall obtain from ABS a class certificate confirming that the barge was manufactured and classed as a Maltese Cross A1 barge, International Load Line certificate, and a Fitness to Proceed Under Tow certificate (confirming approval of the towing plan).

2-8.4 **Mobile, Articulating, and Pedestal Cranes.**

2-8.4.1 **Mobile and Articulating Cranes.** Critical documentation shall include the load charts, which establish the operating envelope for the crane in its various configurations, operations manual, and maintenance and service manual. The lifting capacities (load-radius combinations) are governed by the stability and non-stability (sometimes identified as structural) limits of the crane, which is the product of

such key inputs as the boom length (and weight), reeving, rotate position, hydraulic power, and site conditions. It is important to note that the weight of the load block (and on some models or configurations the wire rope) is considered part of the load.

2-8.4.2 Pedestal Cranes. Pedestal cranes should be procured from manufacturers authorized by American Petroleum Institute (API) to use the API monogram, which is a registered trademark, and attests that the design and quality standards of API have been met. Additional documentation required for these cranes is in the form of load ratings. These cranes are variably rated for static and dynamic conditions. Static ratings apply when there is no relative motion between the crane and the load to be lifted; dynamic ratings apply when there is specific relative motion between them. As with mobile crane ratings, the load block is considered part of the load.

2-8.5 Computer Analyses. When used, computer analyses shall incorporate these requirements:

- (a) The program title and version along with a concise description of program approach, methodology, and assumptions.
- (b) Computer program inputs shall be clearly and fully defined. The model used in the analysis is included and any application default settings that were changed are noted.
- (c) All pertinent or design governing data items (such as loads, load combinations, locations, positions, etc. and the corresponding calculated values) shall be marked, circled, or boxed for easy location and identification.
- (d) Applicable outputs shall be clearly and fully defined.
- (e) Each data item – extracted from the printout and used in the design calculations drawing – shall reference the printout page number.
- (f) Input data files, output data files, and document files shall be provided on CD/DVD ROM and shall be compatible with IBM PC-compatible computers.
- (g) In cases where the estimated computer program inputs are more than 3 percent on the non-conservative side, the entire analyses shall be re-done using more accurate inputs.
- (h) The overall implementation of computer analyses shall be logically organized to permit an efficient review by Government engineers.

2-8.6 Catalog Cuts. The selection of standard commercial assemblies and components shall be accompanied by manufacturers' technical literature (catalog cuts). Each catalog cut shall be marked-up to fully identify the model or size/rating of the item

and supplemental pages with data or information to demonstrate specification compliance. Catalog cuts which show modifications beyond the standard options and all supplemental pages shall bear original signatures and dates of the manufacturer's authorized representative or the responsible PE. Each catalog cut and supplemental page shall identify the crane, drive, and component to which it applies.

Catalog cuts are appropriate for package hoists, spreaders, monorail beams, standard end trucks, speed reducers, brakes, electric motors, runway electrification, master switches, pushbutton control stations, drive control equipment, patented track and end stops and major hydraulic components. Catalog cuts for widely used mechanical and electrical components may be omitted.

2-8.7 **Certifications.** Each certification shall bear the original signature and date of the appropriate responsible individual. Certifications are usually required for the following, where they apply, but additional certifications may be required in particular cases:

- (a) Certificate of minimum breaking force and positive traceability to the wire rope manufacturer;
- (b) Shaft alignment readings to demonstrate compliance with the coupling manufacturer's alignment recommendations. The certification shall include the identification and location of the coupling, the method of alignment, manufacturer's recommendations, and the actual alignment (both offset and angular) that was obtained;
- (c) Adequacy of slewing ring bearing and installation, to confirm the bearing manufacturer's approval of the selection, rigidity and accuracy of the mounting structure, and tensioning of the fasteners;
- (d) Hydraulic fluid cleanliness of the hydraulic system to confirm that initial condition complies with the specification criteria;
- (e) Torsional vibration analysis to confirm that the diesel engine-generator set is free of damaging torsional frequencies in the normal operating speed range;
- (f) Diesel engine emissions authorization/approval documents to confirm compliance with the local air quality regulations for the crane as a new emissions source;
- (g) Air storage tank inspection and pressure test results and distribution to the appropriate local authority to verify compliance with the ASME Boiler and Pressure Vessel code. (A copy of the certificate shall be attached to the tank);

- (h) Approval of periodic overload testing (up to 125%, +5%, of rated capacity) without detrimental effects on the equipment and continued validity of the manufacturer's warranty;
- (i) Brake adjustment records to show the range of allowable settings and the as-installed condition for each;
- (j) Hook non-destructive testing report;
- (k) Hook proof test report;
- (l) Certification of no hazardous material;
- (m) Approval to perform loss of power testing without damage to the crane.
- (n) Additional certifications may be required:
 1. Welders and automatic welding machine operators for qualification with the requirements of AWS D1.1 or D14.1, as appropriate to the crane type and the weld types;
 2. Weld inspectors for non-destructive examination of welds according to American Society for Non-Destructive Testing ASNT SNT-TC-1A;
 3. High-strength structural bolts and nuts to verify U.S. manufacture (with positive traceability) and rotational capacity test data for each production lot and bolt-nut combinations;
 4. Surface preparation and painting to confirm that the surfaces to be painted were properly blast-cleaned and the paint coats were applied in accordance with the paint manufacturer's recommendations; and
 5. Certification that the crane will operate on existing runways or travel paths.
 6. Certification (along with calculations) documenting that outdoor cranes are secure in high winds with the various securing methods supplied with the crane. These methods should be detailed in the technical manuals.
 7. Crane designed parameter ranges (not drive designed ranges) for microprocessor controlled cranes.
 8. Additional certifications as requested by the supported command.

2-8.8 **Technical Manuals.** Crane delivery shall be accompanied by a technical manual. Technical manuals for custom designed cranes are normally comprised of operating instructions, assembly and sub-assembly drawings (which are extracted from its technical documentation drawing set), and catalog cuts of standard commercial items with the manufacturers' literature for maintenance, adjustment, inspection, troubleshooting, and repair instructions. Manufacturers' literature usually includes identification of all parts and a listing of authorized service centers.

A complete set of software programs and programming instructions shall be obtained for cranes with programmable logic controllers (PLCs). For other micro-processor based controls that only allow programming via parameter changes, a complete listing of adjustable parameters and their allowable crane ranges are required.

2-9 **RIGGING GEAR AND MISCELLANEOUS EQUIPMENT. (Applicability includes commercial components)**

2-9.1 **General.** The design and procurement requirements of this section apply to the following equipment used in weight handling operations covered by NAVFAC P-307, including use with multi-purpose machines, material handling equipment (e.g. forklifts), and equipment covered by NAVFAC P-300 and NAVSUP Publication 538:

- (a) Rigging gear (slings, including chain, metal mesh, synthetic rope, synthetic webbing, and synthetic roundslings; shackles, eye bolts, swivel hoist rings, links, rings, turnbuckles, insulated links, hooks etc.)
- (b) Crane structures - jib cranes, bridge cranes, monorails, and davits that do not have permanently mounted hoists. These structures shall be designed in accordance with the applicable sections of this instruction.
- (c) Personnel platforms – suspended from a crane by wire rope or chain slings or directly attached to the crane for lifting personnel.
- (d) Portable manual and powered hoists. These hoists shall be designed in accordance with the applicable sections of this instruction.
- (e) Portable load indicators (dynamometers, load cells, crane scales, etc.)
- (f) Below the hook lifting devices as identified in ASME B30.20 (e.g., spreader beams, plate clamps, magnets, vacuum lifters, container spreaders);

- (g) Portable A-frames, portable floor cranes, and portable gantries.
- (h) Cranes and hoists procured with, integral to, and used solely in support of larger machine systems (milling machines, press brakes, shore power booms, etc.). These hoists and cranes should be designed in accordance with the applicable sections of this instruction.

Usage, maintenance, marking, inspection and testing of items (a) through (h) are covered by NAVFAC P-307. Design of integral lifting attachments (e.g., threaded holes, welded lift lugs on equipment to be lifted) and manufacturer's provided rigging gear used for limited lifts (e.g., offload, initial storage, reloading, and shipment) of that manufacturer's product is not covered.

2-9.2 **Load Test.** Except as noted in NAVFAC P-307, equipment shall be given an initial load test, either by the manufacturer or by the end user prior to first use. Test requirements shall be in accordance with NAVFAC P-307.

2-9.3 **Repairs and Alterations.** Repairs, (including the adjustment or disassembly/reassembly of components to accomplish repairs), maintenance, and alterations to equipment shall be performed in accordance with manufacturer or activity engineering instructions. See NAVFAC P-307 for specific instructions on repairs and alterations.

2-9.4 **Slings.** Slings shall meet the design criteria of ASME B30.9. Additionally, swaged end connections shall be steel or aluminum provided the aluminum swaged connection meets the requirements of EN 13411 Part 3.

2-9.4.1 **Additional Criteria for Wire Rope Endless Slings.** The vertical rated load of an endless wire rope sling shall be based on a D/d efficiency of 50 percent using the following equation:

Equation 2-9 Rated Load

$$RatedLoad = \frac{NRS \times D / dEfficiency \times 2}{DF}$$

Where: NRS is the nominal rope strength listed in Federal Spec RR-W-410, the minimum breaking force listed in the ASTM A-1023, the nominal rope strength provided by the wire rope manufacturer, or the actual breaking strength based on destructive testing of material samples.

D/d Efficiency is taken from the table below.

DF is the design factor (5 or greater).

- (a) An endless wire rope sling specifically used with a pin diameter other than the diameter of the wire rope may have a marked rated

load based on the D/d efficiency given in the table below, however, the sling shall be marked to indicate that pin diameter.

- (b) The load test pin diameter shall be greater than or equal to the specific use pin diameter.
- (c) The sling shall be tested over a pin with a diameter equal to or greater than the wire rope diameter. The test load shall be 200 percent of the rated load determined from equation 2-9 using the efficiency factor derived from the diameter of the test pin, with a maximum efficiency of 78 percent. For a test pin diameter between the table values, the efficiency shall be determined from a curve plotted from the D/d values and efficiency percentages shown (see table 2-5).
- (d) The test load and test pin diameter shall be recorded, including documentation of vendor's proof test from commercial vendors.

Table 2-5 Efficiency Factors for Various Wire Rope Slings
(NAVFAC P-307, Table 14-3)

D/d Ratio	Efficiency Percentage
1:1	50
2:1	65
4:1	75
5:1	78
8:1	83
12:1	87.5
16:1	90
24:1	92.5
40:1	95
over 40:1	100

Where, D/d is the ratio of the diameter of the pin divided by the diameter of the wire rope sling (component rope diameter for multi-part slings). Efficiency is expressed as the percentage of the remaining capacity of each leg of the sling. For D/d ratios between the values shown, use the lower efficiency percentage or, alternatively, plot a curve of D/d versus efficiency percentage.

2-9.4.2 **Additional Criteria for Multi-Part Wire Rope Slings.** Multi-part wire rope slings (sometimes referred to as braided slings) shall have their manufacturer's rated capacity reduced and marked to 70 percent of manufacturer's capacity. Higher capacities based on documented destructive testing of sample slings may be approved by the Navy Crane Center on a case basis. Multi-part slings shall only be used where the D/d efficiency is at least 75 percent (minimum D/d ratio of 4:1 for the component rope).

2-9.4.3 **Synthetic Slings.** Natural fiber rope shall not be used for slings. Sling manufacturers also provide wear protection products that protect slings from sharp corners or edges. Activities should contact the manufacturers of their slings for availability of these specialty protection products when slings are procured. Synthetic slings shall not have painted markings.

2-9.4.3.1 **Synthetic Roundslings.** Roundslings constructed of yarns other than nylon or polyester (referred to here as “alternate yarn roundslings”) shall be used only with: a certificate of proof test that includes the diameter of pin used during actual load test, and the pin diameter used during actual load test shall also be marked on the roundsling.

2-9.5 **Shackles, Links, Rings, Swivels, Eye Bolts, Eye Nuts, Turnbuckles, Blocks, Hooks, and Swivel Hoist Rings.** Shackles, links, rings, swivels, eye bolts, eye nuts, turnbuckles, blocks, hooks, and swivel hoist rings shall meet the following criteria:

- (a) New shackles, links, rings, and hooks shall conform to Federal Specification RR-C-271 for material composition for shackles.
- (b) Stainless steel shackles, hooks, and eyebolts shall be forged from austenitic stainless steel meeting the technical requirements of ASTM A314 for material composition.
- (c) Stainless steel swivel hoist rings shall meet the technical requirements of ASTM A276 (Condition A) for material composition.
- (d) Alloy steel swivel hoist ring material shall conform to ASTM A322.
- (e) Swivel and turnbuckle material (including the bolts and pins of anti-friction bearing swivels) shall meet the same technical requirements of Federal Specification RR-C-271 as for shackles.
- (f) Forged bolts and pins procured with jaw-end type swivels and turnbuckles may be made from ASTM A325 Type 1, ASTM A449 Type 1, ASTM A576 or SAE J429 Grade 5.
- (g) Carbon and alloy steel eyebolts shall meet the minimum requirements for material composition of ASTM A489 or ASTM F541.
- (h) The weld filler material for new welded master links, welded master link assemblies, welded rings, and welded sling links (pear links) shall be in accordance with AWS specification 5.5 or 5.28.
- (i) The welded area for all (old and new) master links, master link assemblies, sling links, and rings, shall be RT inspected in accordance with NAVSEA Technical Publication T9074-AS-GIB-010/271 with acceptance criteria to MIL-STD-2035 class 3 for welds prior to initial use. This is a one-time RT inspection.

2-9.5.1 **Manufacturer Markings.** Rigging equipment requires markings showing the manufacturer. Procurement documents shall ensure the equipment or gear is marked with the manufacturer's name, logo, trademark, or other method to identify the manufacturer.

2-9.5.2 **Eye Bolts.** Shouldered eye bolts, either shouldered nut (through type) or machinery bolt type, and non-shouldered eye bolts (sometimes referred to as plain pattern or regular nut eye bolts) shall be forged steel. Steel nuts shall be equivalent to SAE J995 grade 5 hex nuts as a minimum.

2-9.5.3 **Hooks.** Hooks shall have self-closing latches unless the application makes the use of a latch impractical or unsafe. NAVFAC P-307 provides additional guidance in this area. Hooks used for personnel lifting shall have latches capable of being locked in the closed position.

2-9.5.5 **Blocks.** Rigging blocks shall be designed or selected in accordance with ASME B30.26 and the additional requirements in P-307.

2-9.6 **Below the Hook Lifting Devices.** Custom designed pallets, platforms, hoppers, containers, skids, bolt-on portable padeyes/lugs, and similar weight-handling structures shall be designed and manufactured in accordance with ASME B30.20 and ASME BTH-1, and treated as below the hook lifting devices.

2-9.7 **Portable Manual and Powered Hoists, Lever Operated Hoists, Portable Floor Cranes, Portable Gantry/A-frames, and Cranes Integral to Larger Machine Systems.**

- (a) Portable manual and powered hoists shall be designed in accordance with the applicable sections of this instruction.
- (b) Portable floor cranes shall meet ASME PALD (Portable Automotive Lifting Devices) and manufacturer recommendations.
- (c) Lever operated hoists shall meet ASME B30.21 and manufacturer recommendations.
- (d) Crane and hoists integral to and procured with larger machine systems should be designed in accordance with the applicable sections of this instruction. When possible this instruction should be consulted when specifying the crane or hoist portion or the machine.
- (e) Other equipment shall meet this instruction and the applicable ASME B30 (e.g. trolleys maintained and inspected in accordance with ASME B30.11) criteria and manufacturer recommendations.

2-9.8 **Portable Load Indicating Devices (Dynamometers, Load Cells, Crane Scales, etc.).** Portable load indicating devices shall meet ASME B30.26, with additions and changes as noted below:

- (a) Steel load bearing elements shall have hardness levels no greater than 40 HRC (does not apply to connecting shackle pins). The hardness level of steel load bearing elements shall be documented by actual hardness tests or documentation from the portable load indicating device manufacturer.
- (b) The design factor for load indicating devices with steel load bearing members shall be 5:1. The design factor for load indicating devices with aluminum load bearing members shall be 7:1.
- (c) Some devices have less than these design factors. Such devices shall only be used in the range that ensures the proper design factor. These devices shall be marked or tagged to indicate the reduced maximum rated load.
- (d) These devices shall be designed to not inadvertently disassemble (e.g., due to rotation of assemblies below the device while assemblies above the device do not rotate).

2-9.9 **Insulated Links.** The following requirements shall be included in procurement documents for insulated links.

2-9.9.1 **Link Identification.** Each link shall be uniquely identified with some type of permanent marking to provide positive traceability to its base tram measurement and NDT report.

2-9.9.2 **Proof Test.** Follow P-307, Appendix E requirements.

2-9.9.3 **Dimensional Inspection.** Tram points shall be established across the dielectric structure of the link. Tram reading shall be recorded before and after the proof test. The link shall be rejected if the difference in measurement exceeds the base tram measurement by more than one percent.

2-9.9.4 **Link Nondestructive Test (NDT).** Follow P-307, Appendix E requirements.

2-9.9.5 **Electrical Test.** Follow P-307, Appendix E requirements.

APPENDIX A REFERENCES

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UFC 3-310-04, *Seismic Design for Buildings*, Unified Facilities Criteria Program, <http://www.wbdg.org/>

UFC 3-600-01, *Fire Protection Engineering for Facilities*, Unified Facilities Criteria Program, <http://www.wbdg.org/>

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*, Unified Facilities Criteria Program, <http://www.wbdg.org/>

UFC 4-151-10, *General Criteria for Waterfront Construction*, Unified Facilities Criteria Program, <http://www.wbdg.org/>

UFC 4-213-10, *Design: Graving Drydocks*, Unified Facilities Criteria Program, <http://www.wbdg.org/>

UFC 4-213-12, *Drydocking Facilities Characteristics*, Unified Facilities Criteria Program, <http://www.wbdg.org/>

UFC 4-450-01, *Piers and Wharves*, Unified Facilities Criteria Program, <http://www.wbdg.org/>

UFC 4-860-02N, *Design: Trackage*, Unified Facilities Criteria Program, <http://www.wbdg.org/>

Whiting Crane Handbook, Whiting Corporation, 15700 Lathrop Avenue, Harvey, IL 60426. <http://www.whitingcorp.com/>

Wire Rope Users Manual, Wire Rope Technical Board, PO Box 286, Woodstock, MD 21163. <http://www.wireropetechnicalboard.org/>

APPENDIX B BEST PRACTICES

B-1 DESCRIPTION AND USAGE OF MAIN CRANE TYPES.

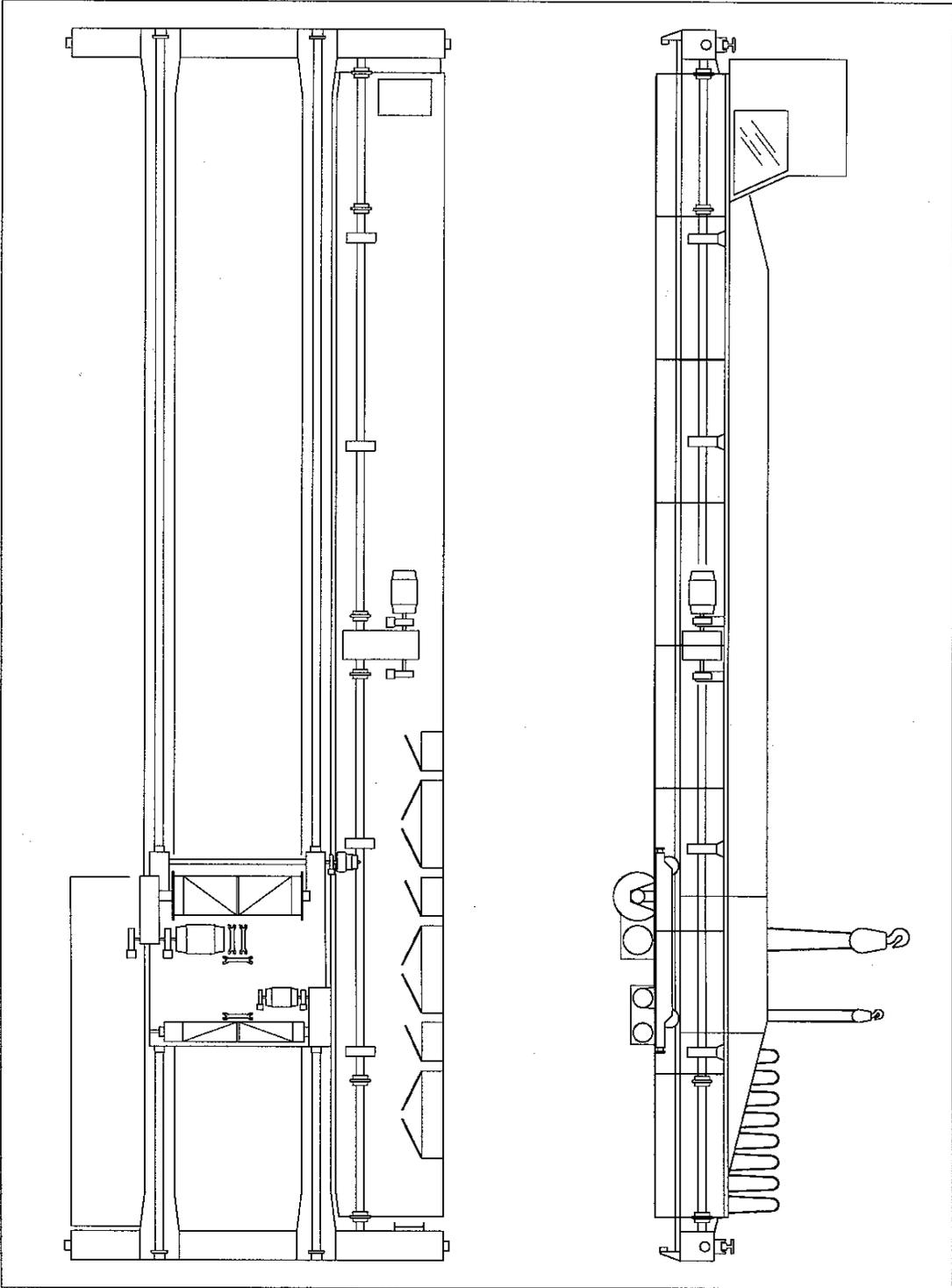
B-1.1 Top Running Bridge Cranes. These cranes are installed on overhead runway rails to provide hoisting (lifting) coverage throughout the entire length and width (span) of the runway. The trolley is equipped with one or more hoists. Top running bridge cranes are ideal for heavy duty service in warehouses, machine shops, maintenance bays, and similar work areas. They function equally well indoors and outdoors. The controls for the cranes may be located in an operator's cab, on a suspended pendant pushbutton station near the floor level, or at a remote control station. Runways and end stops for bridge cranes with top running bridge end trucks are usually constructed as an integral part of the building. The design and condition of the runway should comply with the crane industry standards to ensure satisfactory crane operation.

B-1.1.1 General Description. The main structure of top running bridge cranes is typically two or more parallel bridge girders, which span the runway and rest on end trucks. In the common four-wheel configuration, the end trucks also function as end ties for the bridge girders. The hoists are mounted on a trolley frame, which travels on rails fastened on top of the bridge girders. Crane motions are driven by electric motors. The electric power is transferred from a fixed location near the runway to the traveling bridge by means of collector shoes sliding along rigid conductors parallel to the runway or through extendable loops of flexible conductors festooned along the runway. Figure B-5 shows a typical top running bridge crane with two hoists and a conventional arrangement of footwalks – full-length main and a short auxiliary footwalk.

Older top running bridge cranes typically have two hoists (main and auxiliary) on the trolley for maximum operational utility. The main hoist is capable of lifting the rated capacity of the crane and is relatively slow; the auxiliary hoist has a lower lifting capacity (from 10 percent to 30 percent of the main hoist) but is correspondingly faster. In normal service it is the auxiliary hoist that is used for most lifts since the need for the rated capacity of the main hoist is infrequent. Newer cranes use electronic drive controls to provide a wider range of hoist speeds, making auxiliary hoists less necessary below 50 tons rated capacity.

The bridge girders are always custom designed to fit the runway span. The end trucks/end ties, trolley frame, bridge and trolley drives, and hoists may be manufacturer's standard commercial or custom designed (built-up) assemblies, depending on the application. In either case, many of the subassemblies and components are standard off-the-shelf components. Usually cranes intended for general purpose service (GPS) are in large measure manufacturers' standard designs, those for SPS or handling of ordnance are often built-up custom designs.

Figure B-5 Top Running Bridge Crane



B-1.1.2 Distinctive Features. The stable platform of the bridge structure of top running bridge cranes permits a wide range of design options to suit virtually any operational requirement. The high overhead location of these cranes avoids interference with the floor activity and equipment by lifting the loads over the floor obstructions. Walkways along the bridge girders and the floor on the trolley structure provide excellent accessibility to mechanical and electrical components.

B-1.1.3 Industry Standards. The governing U.S. industry standard for top running bridge cranes is CMAA Specification #70. This specification defines crane service classes – from “standby” to “continuous severe” service. In addition to the crane design requirements, this specification provides the runway design and condition criteria for straightness, levelness, span, and deflection tolerances.

ASME B30.2 focuses primarily on the safety aspects of the design and operation of top running and gantry cranes.

AIST Technical Report (TR) No. 6 contains detailed design specifications for hot metal handling and general service steel mill top running bridge cranes.

The Whiting Crane Handbook, published by the Whiting Corporation, is a comprehensive crane design reference textbook. It is especially useful for estimating weights, dimensions, required runway and building clearances, and maximum wheel loads of top running bridge cranes.

Top running bridge cranes may utilize a package hoist. Design features and industry standards are described in the section on hoists.

B-1.2 Under Running Cranes. A subcategory of bridge cranes, these cranes, also called “under running bridge cranes” or “underhung cranes”, always feature an under running hoist/trolley unit or a trolley with a separate hoist; however, the bridge end trucks may be top running (top mounted on runway rails) or under running (running on the lower flanges of runway beams). The under running runway beams are secured to the roof support structure of the building or by a separate frame constructed for this purpose. The crane configurations are either in the form of a single girder (with a combination hoist/trolley unit mounted on its lower flange) or, infrequently, twin girders (with a trolley spanning the lower outside flanges of the girders). The end trucks may be of the rigid type, with wheels mounted in the end truck frame; or of flexible type, with wheels mounted on swiveling carrier yokes. Crane operator’s controls are usually on a suspended control station near the floor level. The design and condition of the runway, whether for top running or under running trucks, shall comply with industry standards to ensure satisfactory crane operation.

B-1.2.1 Suspension Systems. Runway beams and suspension systems are considered part of the crane for under running cranes with under running bridge end trucks. The suspension systems may be rigid or flexible, depending on the building construction and the available headroom, and are designed to support the bridge end trucks on the lower flanges of the runway beams. In the rigid systems the runway beams are fastened to overhead girders of the building structure or to upright posts

bolted to independent foundations. In the flexible systems the runway beams are suspended on tie rods that can move laterally (like a pendulum) about their individual suspension points; lateral and longitudinal bracing are included in these systems. Standard commercial tie rods, clamps, and various fittings and hardware are normally provided as part of the runway system by the runway manufacturer. Runways for cranes with overrunning bridge end trucks are usually constructed as an integral part of the building.

B-1.2.2 General Description. There is a wide selection of arrangements and design features available for under running cranes. The runway beams and the bridge girders may be in the form of standard structural shapes (wide flange or I-beam sections) or patented (monorail type) track. Navy Crane Center specifies patented track for new crane and runway beam procurements because of its heavier flange that provides longer runway life and resistance to bending. The cranes are most often electrically powered, and with standard commercial wire rope hoists or hoist/trolley units. The electric power is transferred from a fixed location near the runway to the traveling bridge through expandable loops of flexible conductors festooned along the runway or rigid conductors and sliding collector shoes.

The single-girder bridge with a hoist/trolley unit is the most prevalent configuration. It is comprised of the main girder, which carries the hoist/trolley unit, and may have an outrigger beam braced to the upper flange of the main girder. The outrigger beam improves the lateral stability of the main girder, supports the hoist/trolley electrification system, and may support the bridge travel drive. The main girder and the outrigger beam are connected to an end truck at each end. Bridge travel drives on flexible end trucks are in the form of powered yokes (drive heads), typically one on each end truck. On cranes with rigid end trucks, as depicted in figure B-6, the bridge drive may be centrally mounted and drive both end trucks. Alternatively, the end trucks may be equipped with individual drive heads, as shown in figure B-7(a). The powered yoke configuration is shown in figure B-7(b). The hoist/trolley unit has an integral travel drive.

The twin-girder bridge configuration has the upper flanges of the girders braced to each other for lateral stability and carries a trolley frame with an independent hoist on the lower flanges. The end trucks may be of either the rigid or flexible design, with bridge drives as described above. The trolley frame is usually a custom designed built-up assembly.

Figure B-6 Under Running Crane

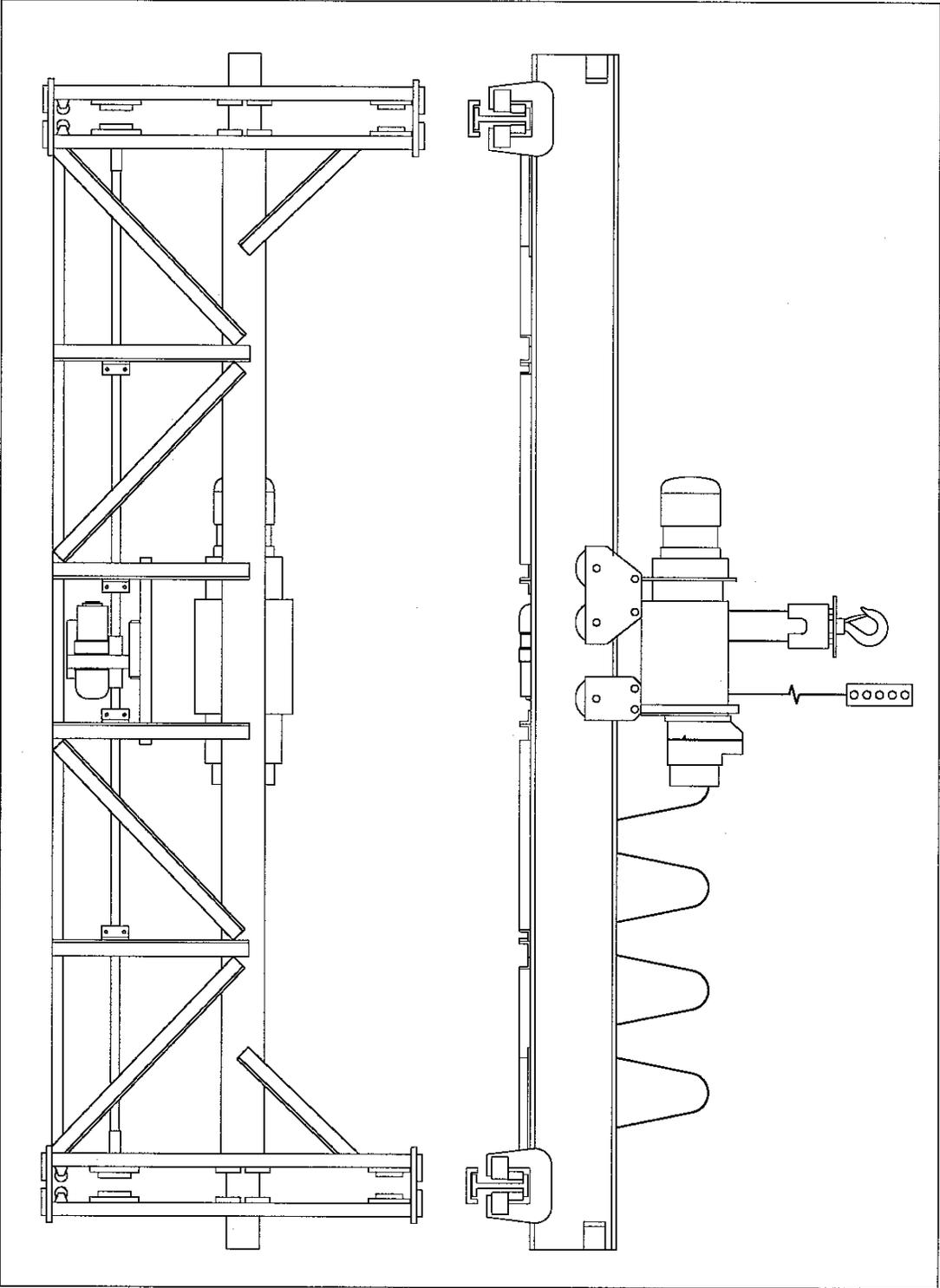
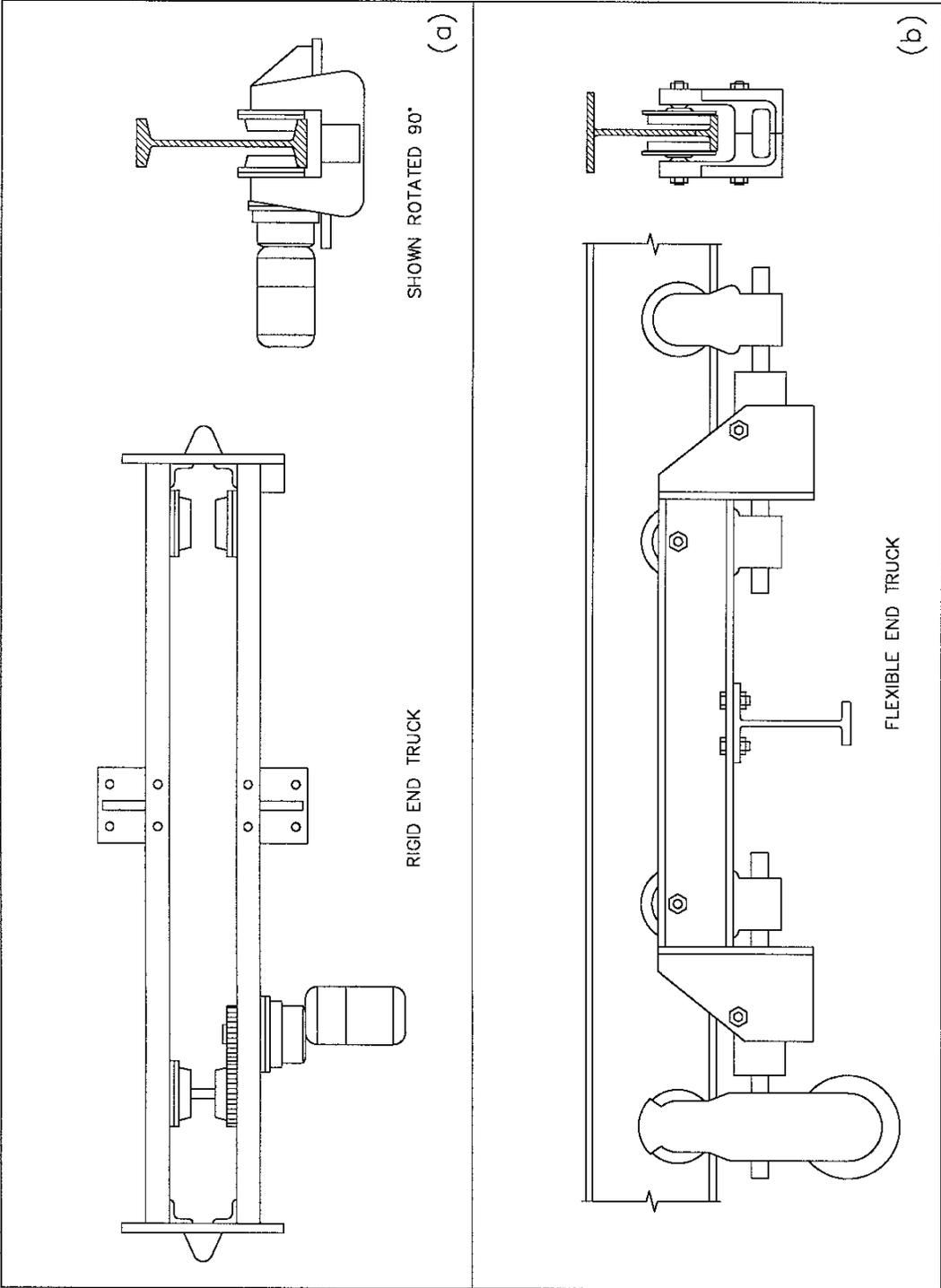


Figure B-7 Under Running End Trucks



B-1.2.3 Distinctive Features. One unique feature available with these cranes is the ability of the hoist/trolley unit or the trolley to cross over between bridge girders of adjoining cranes or travel onto a spur track. Such cross-overs may be direct (girder-to-girder) or across an intermediate transfer section. The hoist/trolley units are standard commercial designs, which are selected from among the catalog models advertised by the major manufacturers of such equipment. The trolleys of twin-girder bridge cranes, can mount either a standard model or a built-up, custom designed hoist.

B-1.2.4 Industry Standards. Due to the wide variety of configurations and design options available with this category of cranes, there are several applicable industry standards. The governing industry standard for the design of runways (including suspension systems) and crane bridges utilizing patented track, is MMA MH27.1 . This specification defines crane service classes from “standby” to “severe duty cycle” service. MH27.1 contains specifications for runways, monorails and trolleys. MH 27.2 contains specifications for runways, monorails and trolleys of the enclosed beam type, typically limited to less than 2,000 pounds capacity.

The governing U.S. standard for the design of top running or under running single girder cranes with under running hoist/trolley units using standard structural shapes is CMAA #74 . It prescribes design requirements for bridge girders in the form of all types of single web structural beams, including specially reinforced, and of box section designs.

These specifications define service classes – from “standby” to “heavy service”. Class C “moderate” service is specified as a minimum to ensure reliability and long service life. These specifications also provide design and condition requirements for straightness, levelness, span, and deflection tolerances for runways for top running and under running cranes.

ASME B30.11 focuses primarily on the safety aspects of the design and operation of under running cranes with under running bridges.

ASME B30.17 focuses primarily on the safety aspects of the design and operation of top running cranes utilizing single girder under running trolley hoists .

Under running cranes typically utilize a package hoist. Design features and industry standards are described in the section on hoists.

B-1.2.5 Torsion Girder Cranes. A hybrid design is a combination of top running and under running crane. Torsion girder cranes feature a single girder that typically rides on top of runway rails like a top running bridge crane, but has a trolley unit that rides on the top flanges of the girder. The hoist is cantilevered over the side of the girder. Possible advantages of this design are a decrease in overall crane weight; however, the design is less stable than either a standard double girder top running bridge crane or a single girder under running bridge crane. No specific industrial standards exist for this equipment and its long term reliability is unknown.

B-1.3 Gantry and Semi-Gantry Cranes. These cranes are similar to the bridge cranes in many respects. Unlike bridge cranes, where the lifting height is established by the elevation of the runway rails, gantry cranes travel on ground-level rails and obtain their lifting height by means of tall vertical frames interposed between the end trucks and the bridge girders. In the case of the semi-gantry cranes, only one end is so configured – the other end is a typical bridge crane running on an elevated rail. They are not limited by any overturning moment due to rated load and may be of any capacity that the rails can support.

Since the only structural support that is required for gantry cranes is a pair of ground level rails, they can be installed in buildings without the major investment of an overhead runway. Semi-gantry cranes are well suited to outdoor installations such as plate yards adjacent to buildings – one end running on a ground level rail and the other on a high rail near the top of the wall.

Gantry and semi-gantry cranes offer broad design flexibility and can be configured for many varied functions. The bridge structure may be of the double girder arrangement with a top running trolley or a single girder with an under running hoist/trolley unit. Crane controls may be located in an operator's cab (on a sill beam, bridge, or trolley) or on a pendent pushbutton station.

B-1.3.1 General Description. The bridge structure is designed to the same criteria as bridge cranes, whichever is applicable to the particular configuration. The upper part of the vertical frame serves as an end tie for the bridge girders. The lower end of the vertical frame incorporates a sill beam with a two-wheel end truck at each end. Sturdy braces between the vertical frames and the bridge girders provide the required strength and rigidity to the gantry structure. All crane motions are driven by electric motors. Electric power is transferred from a fixed location at the elevation of the bridge girders to the crane by means of festoon cable, cable reel, or collector shoes sliding along rigid conductors parallel to the bridge girder end ties.

Virtually all large capacity gantry and semi-gantry cranes are custom designed. Figures B-8 and B-9 show the gantry and semi-gantry configurations, together with some of the available options.

Figure B-8 Gantry Crane

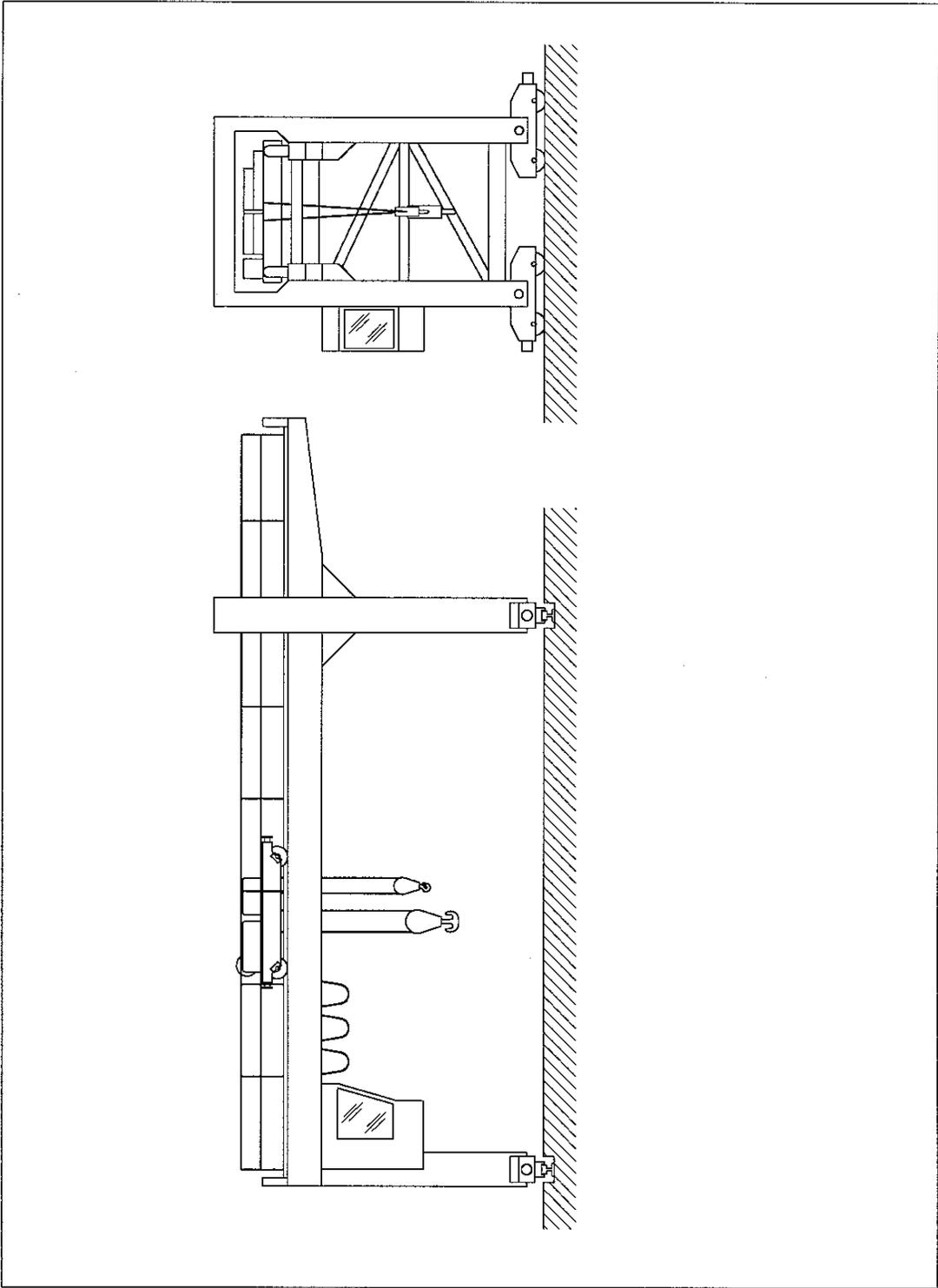
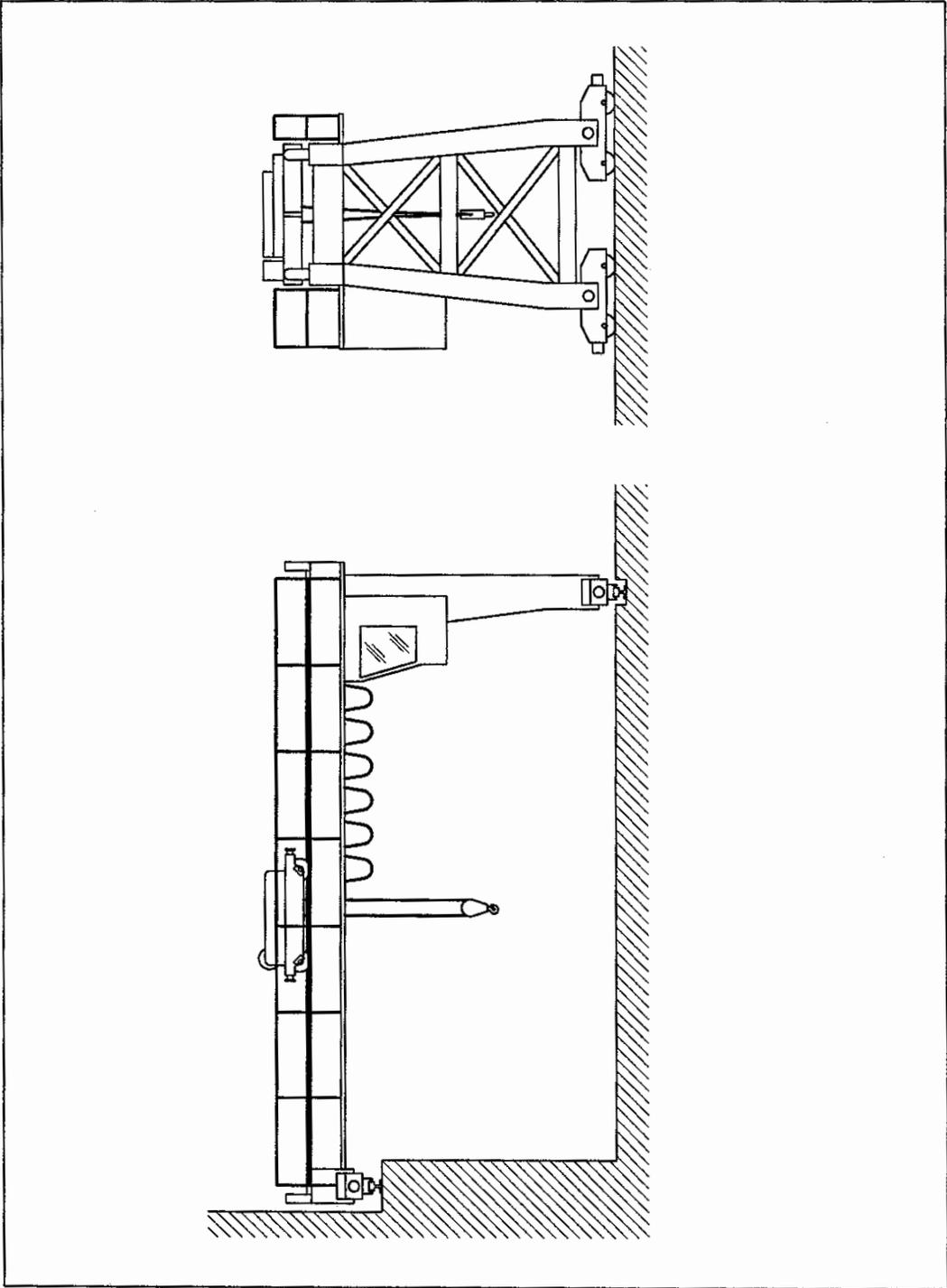


Figure B-9 Semi-Gantry Crane



B-1.3.2 Distinctive Features. Large capacity gantry cranes (usually 40 tons or greater) are sometimes powered by an on-board diesel engine-electric generator set that is mounted on the sill beam. When an operator's cab is provided, it is most often placed on the sill beam. However, depending on the intended service, the operator's cab may be installed on a bridge girder or the trolley.

These cranes can be configured to provide limited capacity outboard of the runway rails by the use of vertical frames with an open center. This arrangement, sometimes called "through-leg", may be used with either overrunning or under running trolleys and hoist/trolley units.

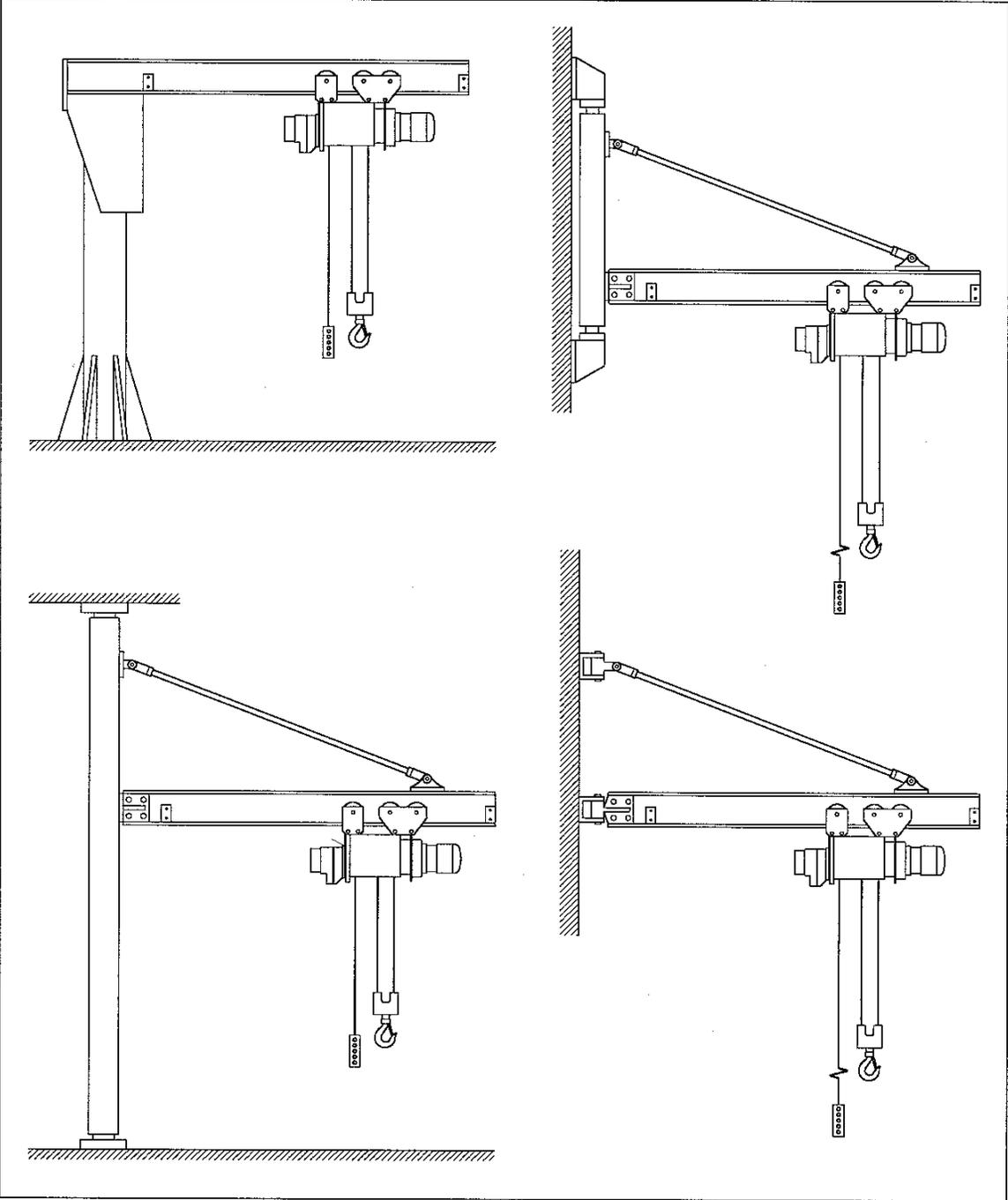
B-1.3.3 Industry Standards. Industry standards for gantry and semi-gantry cranes are the same as for top running bridge cranes and under running cranes, depending upon the gantry configuration.

B-1.4 Jib Cranes, Wall Cranes, and Monorails. This category of cranes encompasses a large assortment of designs, and it is not practical to describe all their variations. They are grouped as stationary (jib) and traveling (wall), and only the most prevalent designs within these groups are described in this handbook. Monorail cranes are described here since they utilize the same hoist and hoist trolley units as other under running cranes.

B-1.4.1 General Description. These cranes utilize various designs of cantilevered booms with cross sections similar to the bridge girders of top running bridge or under running cranes. The cranes may either be stationary jib type (with a pivoting boom mounted on a pillar or wall bracket) or traveling type (with the boom mounted rigidly on a vertical frame) running on rails built into the wall structures. Because of the moment imposed on the boom and the support structure, the rated capacity of these cranes is usually limited to 5 tons. The moments that these cranes impose on the support structure or the wall runway limit their capacity and reach. However, the wide variety of configurations and mounting options, cantilever cranes can be selected or customized to suit virtually any low capacity application. Jib cranes are normally standard commercial items with prescribed mounting instructions; the wall cranes are custom designed to match the particular wall runway.

B-1.4.1.1 Jib Cranes. Jib cranes have a restricted area of hook coverage but are easy to install in any location that requires light hoisting service. Pillar type jib cranes are free-standing, with a pivoting boom that is either fully cantilevered or tie rod supported. Jib cranes that are mounted on wall brackets have the boom foot rigidly connected to a vertical mast and the boom tip supported by a diagonal tie rod secured to the top of the mast. The ends of the mast pivot on two in-line bearings built into the surrounding building structure. Alternatively, the mast may be omitted and the boom foot and upper end of the tie rod attached directly to in-line bearings supported by the wall column. Figure B-10 shows four varieties of stationary jib cranes. These cranes are available as standard commercial equipment.

Figure B-10 Stationary Jib Cranes



Patented track booms are available by specific request at additional cost; however, the booms on these cranes are most often in the form of single-web girder. The hoist is typically an under running hoist/trolley unit. The individual motions may be electrically driven and controlled from a pendant pushbutton station or manually operated.

B-1.4.1.2 Wall Cranes. These cranes travel along the wall runway. The typical runway is comprised of a single rail sized for the vertical loads and two widely separated moment-carrying wide-flange structural beams. The lower beam provides a running surface on the outer surface of its flange. The upper beam can be installed in a similar manner, as shown in figure B-11(a), or so that the inner faces of its flange serve as the running surfaces, as shown in figure B-11(b). The running surfaces of the beams can be upgraded by lining them with welded-on finished medium carbon steel plates. The design of the single rail end truck (carriage) is similar to that of a top running bridge crane, with double-flanged driven travel wheels. The moment-carrying wheel assemblies run on crowned idler rollers. The two lower wheel assemblies are built directly into the vertical frame; the two upper wheel assemblies are mounted in brackets which are pinned to the vertical frame for load equalization, as shown in figure B-11(b). Some wall cranes have two load ratings – with a higher capacity at the shorter reach, and lower further out. These cranes are usually custom designed.

The booms may be single beam type (either structural section or patented track) mounting an under running hoist/trolley unit or a twin beam design with a top running trolley. The booms are supported with tie rods or knee braces, as best suited for the particular application.

Wall cranes are usually electrically powered on all motions and may be controlled from an operator's cab or a pendant pushbutton station. Electric power is transferred from a fixed location near the runway to the traveling vertical frame by means of collector shoes sliding along rigid conductors parallel to the wall. Light duty cranes may have manually operated hoist and trolley drives of the types available for under running cranes.

B-1.4.1.3 Monorail Systems. Monorail installations utilize the same hoists and hoist/trolley units as under running cranes. Monorail layouts may be straight, with curves, open or closed loops of patented track. A typical monorail system consists of a package hoist/trolley unit mounted on a structural steel rail. New monorail systems usually utilize patented track runways with sections made by welding a standard structural shape to a special t-rail to create the runway. The suspension can be either laterally braced flexible type or rigid. Standard electrification hardware is available to permit smooth crossing of collector shoes at the switches to maintain uninterrupted electric power. Motion control is normally from a control station suspended from the hoist/trolley unit. Alternatively, the motions may be controlled by remote means, such as infrared or radio signals.

B-1.4.2 Distinctive Features. Jib cranes are characterized by their simple mounting provisions. They are bolted directly to the building structure (wall or steel column), bolted at floor level to a heavy concrete anchor block, or mounted between supports above and below the column.

Wall crane installations, on the other hand are distinguished by the three-part runway designs, which are an integral part of the building wall. Although their lifting capacity is limited and the area of hook coverage is restricted, jib and wall cranes are well suited for many applications.

Monorail systems may feature standard track switches, both electrically and manually operated, to permit hoist/trolley units to transfer between adjacent sections of the monorail layout. The switches include interlock mechanisms for positive track alignment and automatically activated forks (stops) to prevent a hoist/trolley unit from rolling off an end of the track. Electrically powered hoist/trolley units on curved track require rigid electrification curved to follow the track at a fixed distance.

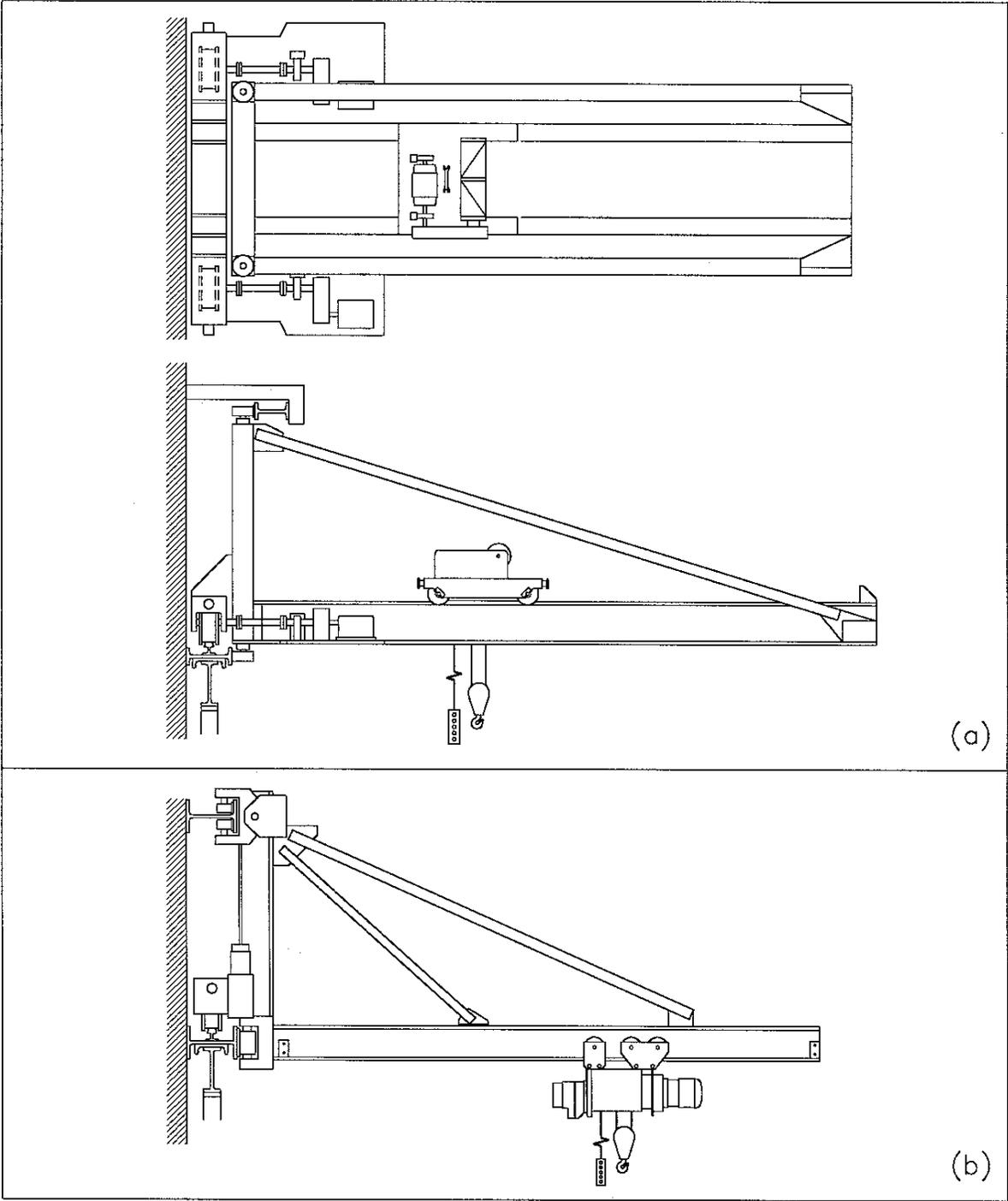
B-1.4.3 Industry Standards. There are no industry standards for this specific category of cranes. Various portions of the design are included in the standards of top running bridge and under running cranes. The safety aspects of the design and operation are addressed in ASME B30.2 and ASME B30.11. ASME B30.2 includes wall cranes in its scope. ASME B30.11 includes jib cranes and monorails in its scope.

These cranes normally use standard commercial package hoists or hoist/trolley units. These include hand manually, electrically, and air operated hoists and trolleys. Duty class selection is made on the basis of specific application. Design features and standards of these elements are covered in the section on hoists.

MH 27.1 is applicable for cantilever cranes that use patented track structural components.

MIL-C-82017, Cranes, Jib, With Accessories, provides design standards for jib cranes.

Figure B-11 Traveling Wall Cranes



B-1.5 Portal Cranes. Portal cranes derive their name from the opening (portal) between the legs of the structure (gantry), which permits the passage of vehicles in the congested environment of wharves and piers. They are also popularly called revolving gantry, dockside, whirler or whirley cranes. These cranes run on two widely spaced rails at ground level close to the edge of the wharves and piers that they service. The gantry supports a rotating superstructure (upper works) with a luffing boom. Gantry clearance should be sufficient for the expected traffic below the crane.

There is a striking visual difference between the older portal cranes (shown in figure B-12) and those of newer design and manufacture (shown in figure B-13). The older cranes have a deep triangular truss boom and a cage-like gantry consisting of hundreds of riveted structural members. The newer cranes have a slender lattice boom and smooth, streamlined, gantry structure consisting of a few large weldments bolted together. The rated capacities and hook reaches range up to 170 tons and 120 feet, respectively. The elevation of the machinery deck, boom hinge, and operator's cab are of major importance to the utility of the crane – the boom hinge position controls the crane's reach over nearby obstructions and the position of the operator's cab determines his field of vision. There are significant differences between Navy and commercial portal cranes.

- a) Navy cranes are normally "straight-line" rated for a significant portion of their overall reach; for example, 50-tons from 55-foot radius to 95-foot radius. Commercial cranes are variably rated; for example, 75 tons at 55-foot radius and decreasing to 12 tons at 95-foot radius.
- b) Navy cranes are typically required to travel around tight curves at the head of dry-docks, which necessitates complex travel truck designs to compensate for increase in the effective rail gauge. Commercial cranes usually travel on straight or gently curving tracks with a fixed rail gauge. The geometry of this effect is explained in paragraph B-3.10.
- c) Navy cranes are typically self-powered with an onboard diesel engine-generator set. Commercial cranes are often shore-powered by means of a gantry mounted cable reel connected to a fixed electric terminal near one rail. The cable reel pays out or takes up the cable as the crane travels back and forth along the track.

B-1.5.1 General Description. The main structural components of portal cranes are the rotating upper works (including the machinery deck, A-frame, boom, and strut) and the traveling portal base. Each of the four corners of the gantry is supported by a complement of travel wheels. A system of equalizers (rocking beams) under each corner distributes the corner load equally to all wheels. Pairs of wheels are mounted in the travel trucks, which are free to swivel (steer) to follow the curvature of the track. Typically, 1/3 or 1/2 of the wheels are driven.

The upper works is comprised of the machinery deck on which are mounted two or three hook hoists, luffing hoists, rotate drive, electrical controls and resistors, diesel engine-generator set, fuel tank, A-frame, boom, counterweight, and operator's cab. The diesel engine-generator set and fuel tank may be installed on the portal base cap to make them more accessible for servicing. The entire upper works is supported by roller path and king pin assemblies or a slewing ring (rotate) bearing. With only rare exceptions, all drives on Navy portal cranes are electric. Commercial portal cranes may use hydraulic (hydrostatic) drives, which may offer some tangible advantages over the electric drives – compactness and lower costs.

Although less noticeable than the difference between the booms and gantry structures, the rotate mechanism of the newer cranes differs even more dramatically from the old roller path design. Unlike the older cranes, which rotate on a simple assembly of exposed rollers on bent rail or cast segments with a king pin for centering, the newer cranes rotate on a precision sealed roller bearing.

B-1.5.2 Distinctive Features. Portal cranes have the ability to travel anywhere within their rail network (circuit) and provide heavy lift capability at a reach unmatched by any other outdoor traveling crane. The wide and high portal opening with narrow travel trucks and gantry legs of the portal cranes minimize obstruction in the busy work areas where they operate.

Corrosion and control of birds roosting are always major maintenance concerns with any outdoor crane, but this problem is particularly acute with the intricate cage-like construction of the old gantries and booms with crevices and water pockets throughout. The mainly welded construction of newer cranes presents a smooth exterior that minimizes this maintenance burden.

Figure B-12 Portal Crane (Older Design)

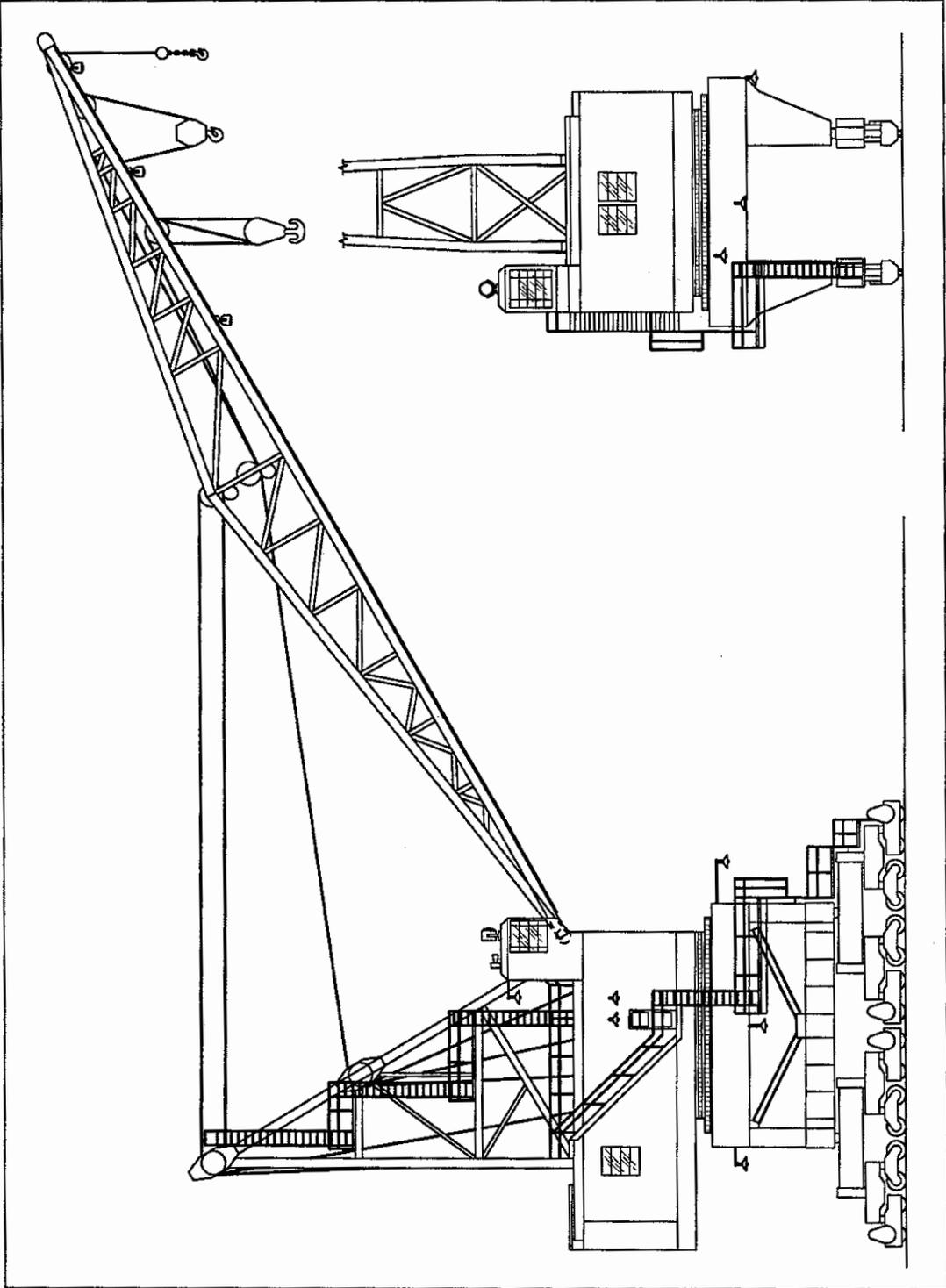
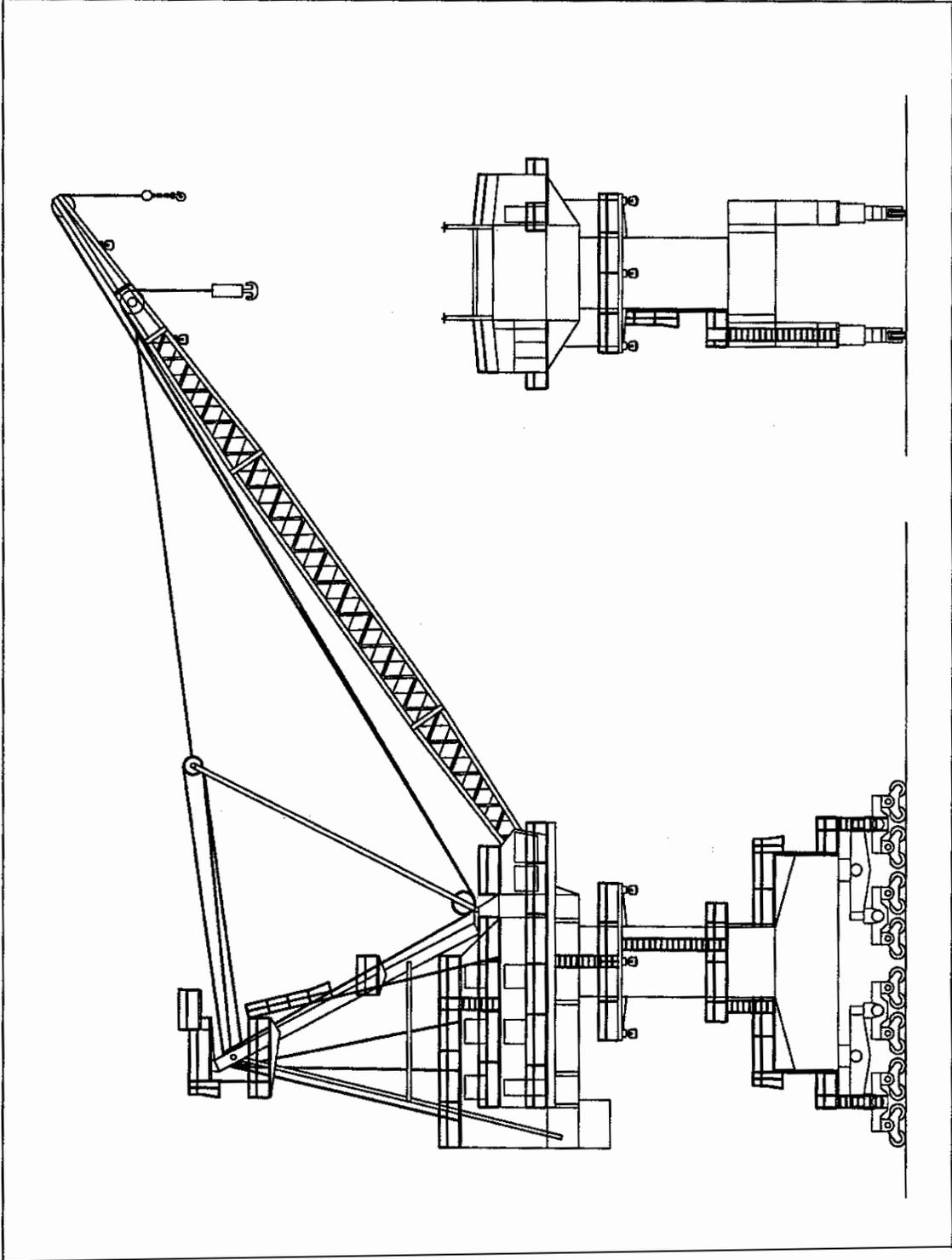


Figure B-13 Portal Crane (Newer Design)



B-1.5.3 Industry Standards. There are no industry design standards for portal cranes. Structurally these cranes are designed in compliance with the applicable requirements of the AISC 360.

ASME B30.4, focuses primarily on the safety aspects of the design and operation of the cranes.

API Specification 2C prescribes a method for calculation of loads on the slewing ring bearing. However, since slewing ring bearings and their mounting are a specialty of a limited number of manufacturers, their guidance for bearing selection and installation should be followed when it is available.

B-1.6 Floating Cranes. Floating cranes are comprised of the upper works of portal cranes mounted on barges. These cranes are intended for operation in sheltered waters but are designed for towing in the open sea. They are not self-propelled, except that they are equipped with capstans, which pull on mooring lines to reposition themselves over short distances. Floating cranes are versatile – they can be positioned between the shore and the vessel for rapid loading or off-loading, inside a flooded dry-dock in close proximity to the work area, or anywhere within the basin. As with the portal cranes, the older designs (shown in figure B-14) feature deep triangular truss booms, while the newer cranes (shown in figure B-15) have slender lattice booms. Older floating cranes are “straight-line” rated; the newer designs are variably rated through most of the operating range.

B-1.6.1 General Description. The upper works of the floating crane is supported on a structural element built into the barge, usually near the stern. As a counterbalance to the crane, the bow end of the barge deck is provided with a thick (usually 1.5 to 2.0 inches) steel cargo lay-down area. The upper works, including the slewing ring bearing, is similar in design to that of the portal crane, with only a few exceptions:

B-1.6.2 Distinctive Features. Since it is desirable to maintain a low center of gravity for stability in the water, the elevation of the machinery deck is restricted. Compared to portal cranes, all portions of floating cranes are at a low elevation. To mitigate this condition, the boom hinge pin and operator’s cab, are often raised above the roof level of the machinery house. The rated capacities and reaches range up to 115 tons at 80 feet, respectively. The booms frequently have a long extension in the form of a jib to increase the reach of the whip hook for servicing masts and periscopes of Navy vessels.

A conspicuous boom rest is located at the bow end to support the boom when the crane is not operating and to secure it for towing. A pilohouse is sometimes installed at the bow, often within the boom rest.

B-1.6.3 Industry Standards. The design of barges is regulated by Rules for Building and Classing Steel Barges, published by the American Bureau of Shipping (ABS). The barge design includes the reinforced circular column, which supports the roller path or the slewing ring bearing of the floating crane upper works. Structurally these cranes are designed in compliance with the applicable requirements of the

Manual of Steel Construction, published by the American Institute of Steel Construction, Inc.

API Specification 2C prescribes a method for calculation of loads on the slewing ring bearing.

ASME B30.8 focuses primarily on the safety aspects of the design and operation of these cranes.

Various U.S. Coast Guard regulations impose seaworthiness, safety, and human occupancy requirements.

B-1.7 Container Cranes. Container cranes are optimized for rapid loading and off-loading of standard shipping containers. The containers are transferred between the container ship and the dock storage area or the truck carriers. The crane rails are straight and the waterside rail is located close to the edge of the wharf or pier. Container cranes in commercial service are often shore-powered, with the electric power cable spooled on a reel and laid in a trough running parallel to the land side rail; those in Navy service are self-powered with an on-board diesel engine-generator set. These cranes are equipped with several standard lengths of frames (spreaders) to engage different sizes of containers both above deck and inside the ship's holds. The standard maximum weight of containers is either 40 or 50 long tons. It is a common practice to provide a load beam with one or several hooks, which can be readily installed in place of the spreader for handling bulk cargo. Figure B-16 shows a typical container crane.

Figure B-14 Floating Crane (Older Design)

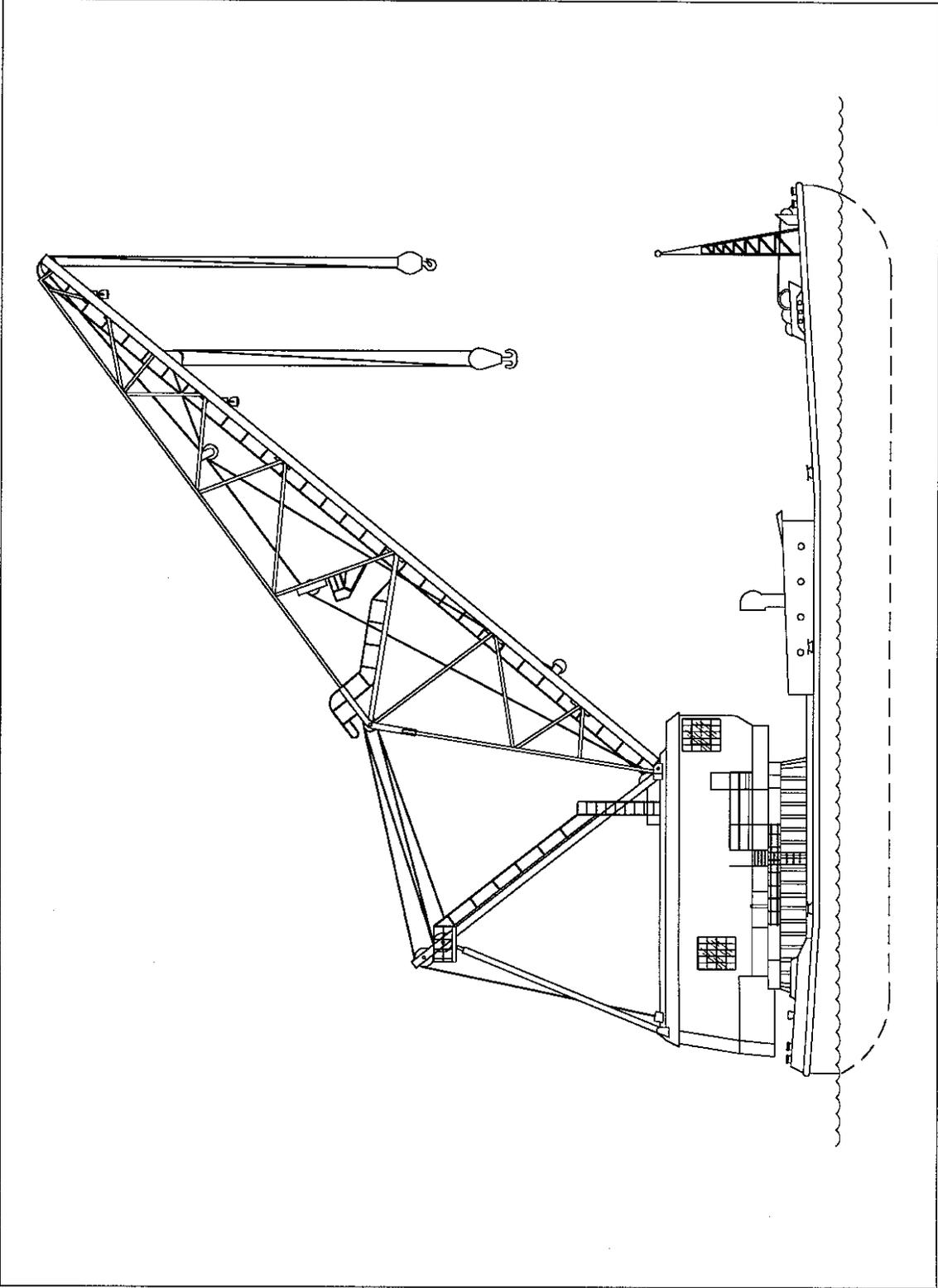
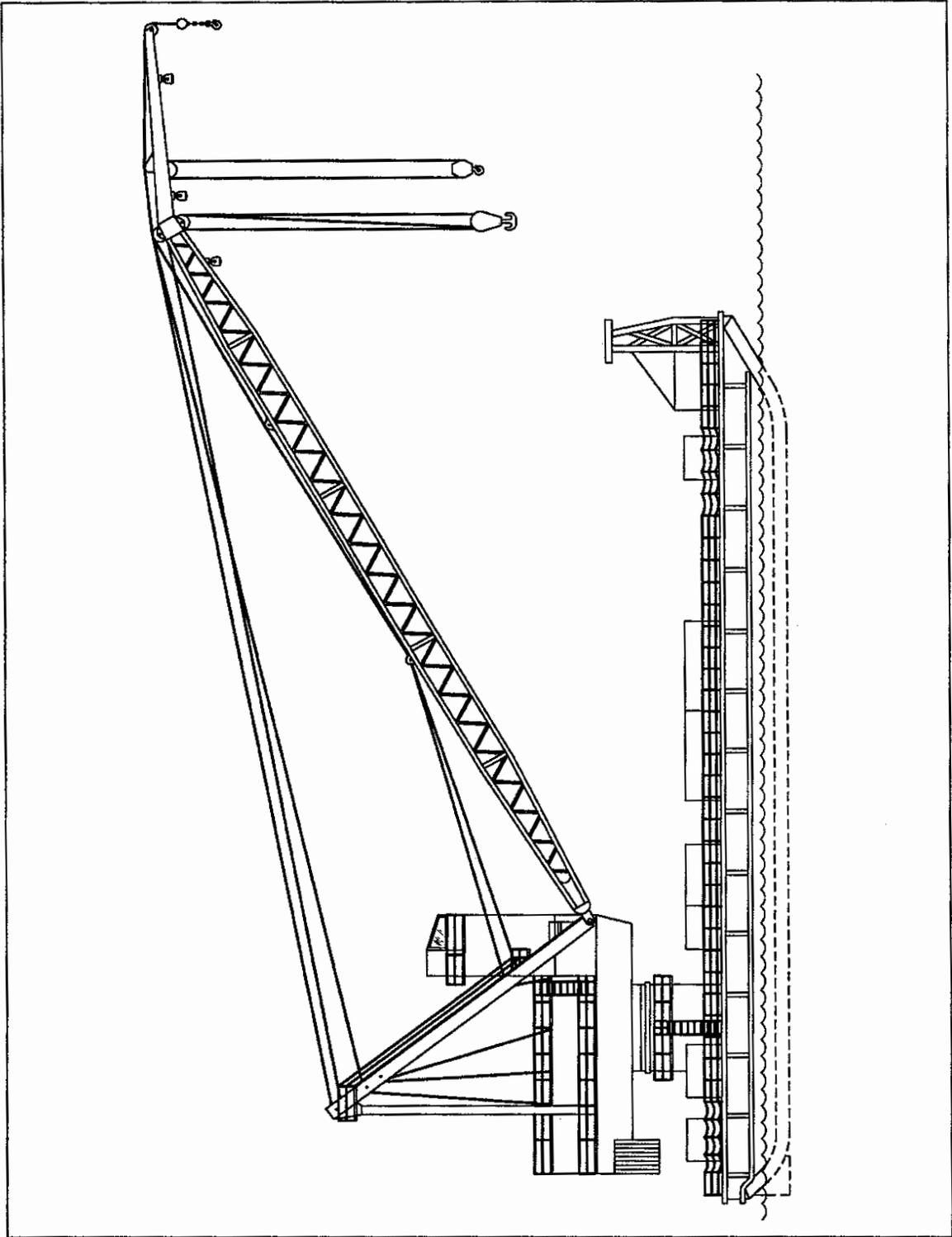


Figure B-15 Floating Crane (Newer Design)



B-1.7.1 General Description. The primary structural components of container cranes are the gantry, horizontal main beams, luffing boom, and an overrunning or under running trolley with an adjacent operator's cab. When in use, the boom is lowered to the horizontal position in line with the main beam and above the container ship deck. The boom length is designed to reach across the entire width of the stacked containers on the ship. The horizontal main beams form a rearward extension of the boom over the container storage area on the wharf or pier. These cranes have non-rotating upper works; they reposition themselves on the rails to be in line for each row of containers to be handled. The boom is luffed up to clear any ship superstructure before the crane moves along the rails. When the container crane is not in use, the boom is locked in a nearly vertical position.

The containers are engaged by twist locks located in the corners of the lifting frame (spreader). The spreaders may be of fixed length designed to engage only one size of containers, or they may be telescoping to fit any length of container. The standard dimensions of containers are 8 feet high, 8 feet wide, and 20 to 40 feet long. The spreaders are readily disengageable from the hoist head block.

The hoist may be located either on the trolley with the wire ropes descending downward from the wire rope drum to the four sheaves in the corner of the head block frame, or in the machinery house with the wire ropes routed horizontally to the trolley and downward to the head block frame sheaves. Rope towed trolleys offer reduced weight of the trolley and protection of mechanical components by being in the machinery house. The four wire ropes are independent (non-equalized). The head block is designed for quick mechanical and electrical connection to its counterpart on the spreader.

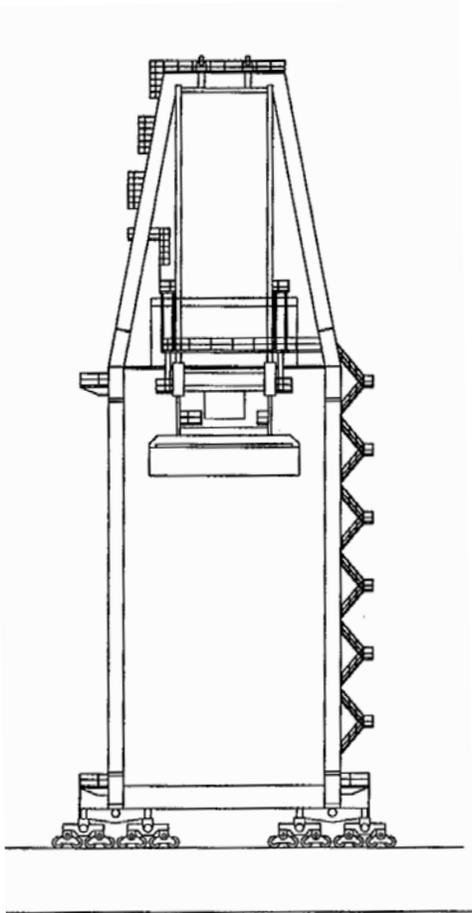
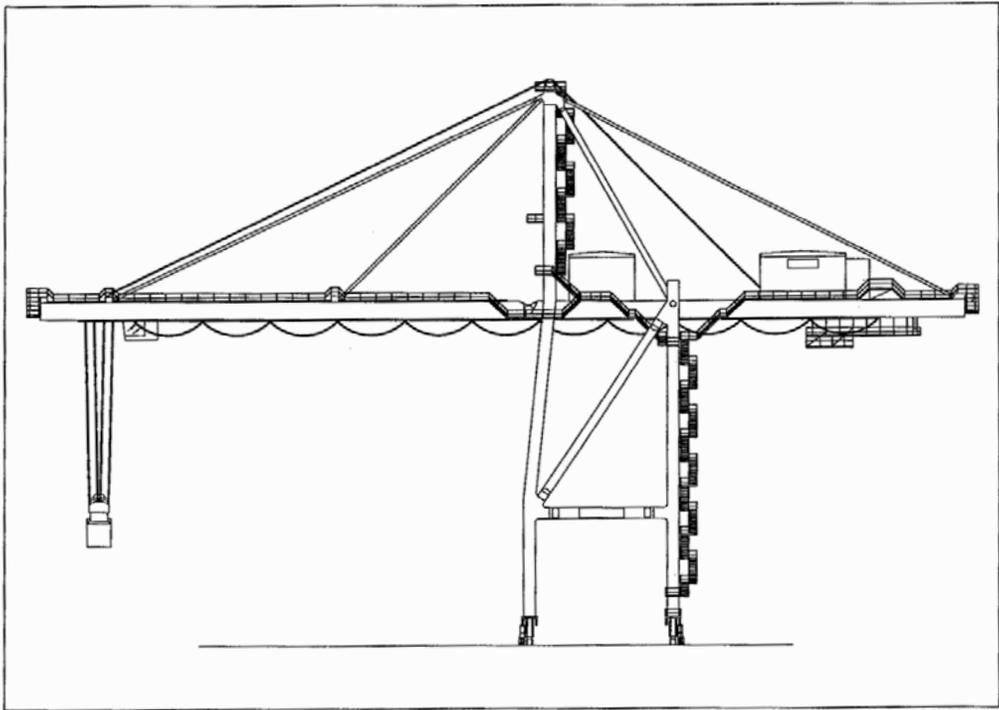
B-1.7.2 Distinctive Features. The structure is a rigid traveling gantry with a fixed main beam and a luffing boom. When the boom is in the horizontal (operating) position, it is supported by steel stays, which are attached to the top of the A-frame. The machinery house and an integral or separate diesel engine-generator set enclosure are equipped with a built-in service crane (usually a bridge crane) of adequate capacity to handle the heaviest components that may require removal. The machinery house and enclosure floors have removable hatches through which the service crane hooks can reach the ground level.

These cranes are designed specifically for handling standard containers at a rapid rate (up to 35 per hour) and a high degree of safety.

B-1.7.3 Industry Standards. There are no industry standards specifically for the design of container cranes. Structurally these cranes are designed to comply with the applicable requirement of Manual of Steel Construction, published by the American Institute of Steel Construction, Inc.

ASME B30.24 focuses primarily on the safety aspects of the design and operation of the cranes.

Figure B-16 Container Crane



B-1.8 Locomotive Cranes. Locomotive cranes are used for railroad service applications where access by other cranes is not practical or desired.

B-1.8.1 General Description. Locomotive cranes are typically cab operated lattice boom cranes with a powered rotate function. The crane is mounted on the deck of a rail mounted car. They are powered by diesel engine-generator sets and may be self-propelled.

B-1.8.2 Distinctive Features. They are available with free over-side rated capacities of up to 55 tons and up to 150 tons when set on outriggers.

B-1.8.3 Industry Standards. There are no comprehensive industry standards for the design of locomotive cranes. Standard commercial locomotive cranes are designed to comply with safety requirements of ASME B30.5.

B-1.9 Mobile Cranes. Mobile cranes are available in a variety of configurations – wheel-mounted or track-mounted (crawler); telescoping boom, fixed length lattice boom with reconfigurable sections, or articulating boom; and crane operator stations on the chassis, on the upper works, or both. These cranes are standard models of established manufacturers. They are designed for off-road use or highway travel/transportation (sometimes both) and of necessity are optimized within the highway weight and size restrictions. As a direct result of these restrictions, the stability of mobile cranes is poor compared to that of portal cranes.

B-1.9.1 General Description. Wheel-mounted cranes (as shown in figure B-17) known as truck cranes and all-terrain or AT cranes utilize an automotive style of chassis with a standard driver's cab for road travel. Crane controls may be located in the same fixed cab or a separate operator's station on the rotating upper works. On track-mounted crawler cranes (as shown in figure B-18) a single cab is used for driving and crane operation. Mobile cranes are equipped with hydraulically extendable outriggers near the corners of the chassis, which shall be deployed to stabilize the crane when making a lift. On some models, the outriggers may not have the capability of relieving all of the weight from the wheels. A counterweight is always installed on the upper works, which rotates on a moment carrying bearing or, on older cranes, rollers/roller path with hook rollers to take up the overturning moment.

Telescoping booms are luffed and extended by means of hydraulic cylinders and (sometimes) internal wire ropes or chains. Latching boom telescoping cranes can be considered a subset of telescoping booms. This design utilizes one telescoping cylinder that extends or retracts each boom section individually; the section is then pinned into position. This design usually results in a higher capacity boom, however the tradeoff is lack of infinitely variable boom length (within the range of boom lengths) and typically the inability to telescope the same rated load as when the boom is pinned into position. There are numerous variations of latching booms each with specific operational characteristics. Lattice booms are luffed by means of a wire rope hoist and sheaves at the top of the upper works. The design of lattice booms permits disassembly of the boom sections to shorten their length for road travel or to increase

the length for longer reach when required. Articulating booms are articulated and extended/retracted by means of hydraulic cylinders.

The crane functions on mobile cranes are generally powered by hydraulics – either motors or cylinders. Some models use a combination of hydraulic and mechanical drives. The reeving systems are single reeved and arranged for easy conversion to any of several configurations for the desired combination of hoist speed-lifting capacity.

B-1.9.2 Distinctive Features. The main virtue of mobile cranes is their ability to travel to the work site and position themselves in the most advantageous location for the task. Their foremost weakness is limited stability, even when set on outriggers, and limited ability to travel with any significant load on the hook. Operators' understanding of the site/ground conditions and the reference to the proper chart for crane stability limits for each particular upper works orientation and boom length are critical to safe operation.

B-1.9.3 Industry Standards. There are limited industry standards for the design of mobile cranes. ASME B30.5 for mobile cranes, and B30.22 for articulating boom , focus primarily on the safety aspects of the design and operation of these cranes.

SAE J1028 provides in graphic form the limiting position of any load for operation within the major working quadrants. SAE J1289 provides the methodology for calculating the tipping load of a mobile crane. Other SAE standards used in design are noted in paragraph B-2.8.

B-1.9.4 Mobile and Articulating Crane Options. Mobile and articulating cranes are typically ordered as a base model with options. Available options vary by manufacturer, type of crane, and specific model. Articulating cranes typically have fewer options than mobile cranes.

B-1.9.4.1 Recommended Options When Available.

Event recorders and data loggers connected to the LMI/RCL system are available on some LMI/DRCL systems. These devices are invaluable aids in incident investigation

Outrigger span detection device. This device assists the operator in extending the outriggers the correct distance. This will be an OSHA required item for construction in the near future. Additionally some models are available with outrigger or loading sensors.

3rd wrap detectors that warn the operator when the bottom layer of rope is reached and stop operation when the rope has approximately three wraps left. Additionally a drum follower or other slack line type device to warn of mis-spooling.

Lebus Lagging or other grooving on hoist drums to assist in proper rope spooling.

A working range limiter may be useful when the crane is working in tight locations as an aide to the operator and rigger.

Wind speed indicator.

Video cameras monitoring various areas of the crane including backup cameras and hook area are available. These cameras improve the operator's visibility of blind spots and other hard to see areas. Mirrors and drum rotation indicators are lower technology versions of this philosophy.

B-1.9.4.2 Boom Options. There are multiple boom options and boom ancillary equipment options available for almost all telescoping and lattice boom cranes. Articulating cranes have fewer options. Choosing the correct boom option(s) begins by determining what the cranes mission requirements are. These options include:

Lattice swing-away jibs – these increase the height and reach of telescoping boom cranes and available in numerous configurations including offsettable, telescoping folding, and insert sections. The lattice swing-away jib is the most common boom length increase option on Navy telescoping boom cranes.

Manual boom extensions – also known as “power-pinned flies”, these are available on some telescoping cranes and act as an additional telescoping section; these sections, however, are not telescoped under power and typically have their own load chart.

Luffing jibs – typically available on larger lattice boom cranes or very large telescoping boom cranes; these lattice sections use one of the winches to luff. These are not very common for Navy mobile cranes.

Boom Inserts – not an option per se, but lattice boom cranes typically come with a minimum and maximum base boom length along with a minimum and maximum jib boom length. These lengths are established by using standard length boom inserts in addition to the base and tip sections. The crane may be ordered with a minimum length base boom or a maximum length base boom depending upon the mission.

Auxiliary lifting nose – also known as a “rooster sheave”. This is a very common option and provides for easier operation of a crane with two hoists reeved simultaneously.

Pivoting boom heads, quick reeve boom heads, and quick reeve blocks are recommended options when the mission dictates re-reeving.

Winch (wire rope hoists) – this is typically an option for an articulating crane.

B-1.9.4.32 Other Options. The following is not intended to be a comprehensive list of mobile crane options but is intended to give a brief synopsis of some important options that should be considered when ordering a mobile crane.

A wide variety of wire rope is available from the manufacturer. The requirements of paragraph 2-3.13 apply.

Steering options include 4 wheel steer, 2 wheel steer (front or rear), and crab steer depending on the model. The option required will depend upon the maneuverability needed by the activity. Additionally, 4-wheel drive or 6-wheel drive is available on some models.

Operator comfort options to increase operator attention and efficiency such as tilting cabs, hydraulic counterweight installation systems, carbody jacking systems, various air conditioning and heating options, and weather based options such as cold weather starting options should be carefully considered.

Maintenance reduction options such as stainless steel exhausts, battery disconnect switches, guardrails for winch machinery areas to assist inspection and maintenance personnel in performing their work, and tire inflator kits should be considered.

Operational requirements should dictate the need for certain options such as high speed or high line pull options, 3rd or 4th drums, indoor treads, 360 degree swing locks, free fall, more powerful engines, or various lighting options.

For cranes that are being deployed to contingency areas the engines may not be able to meet the latest tier requirements set by the EPA and may need to meet 2007 EPA requirements due the quality of diesel fuel available in these areas. Coordination between the activity, the crane manufacturer, and the activity supplying the fuel is required to ensure the crane will be compatible with the available fuel.

B-1.10 Pedestal and Revolving Gantry Cranes. Pedestal cranes are any of a variety of base mounted lattice, telescoping, or articulating boom cranes designed to service a particular worksite. These cranes are typically comprised of standard commercial revolving upper works (however some uppers may be custom designed) on either a fixed or rail-traveling base.

B-1.10.1 General Description. The booms may be of the fixed-length lattice, telescopic, or articulating design. The cranes may be designed for road transportability and ready installation on various support structures, and of necessity, lack some of the customary maintainability and service life prolonging features of Navy portal and floating cranes. They may be powered either with an onboard diesel engine or from a remote electric power source. The drives are typically hydraulic or direct mechanical type.

B-1.10.2 Distinctive Features. Pedestal cranes are mounted on tubular steel or other structural foundation, while the revolving gantry cranes are installed on a base similar to that of portal cranes. Drive machinery on some standard designs is only partially enclosed by a machinery house, but the exposed equipment is required to have other means of adequate protection from the corrosive marine environment. Stainless steel hydraulic lines and special exterior paints are among standard options.

Figure B-17 Mobile Cranes (Wheel-Mounted)

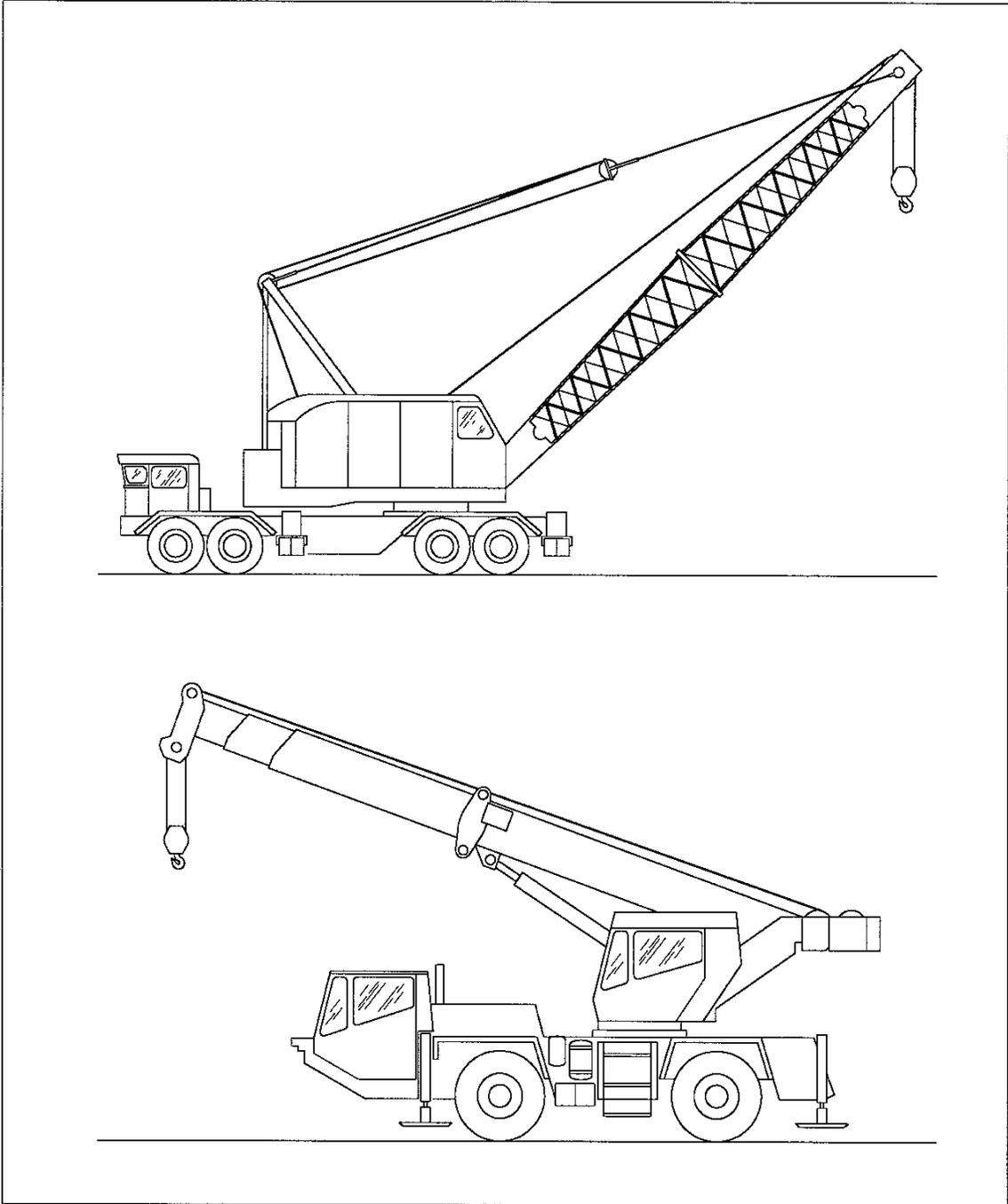
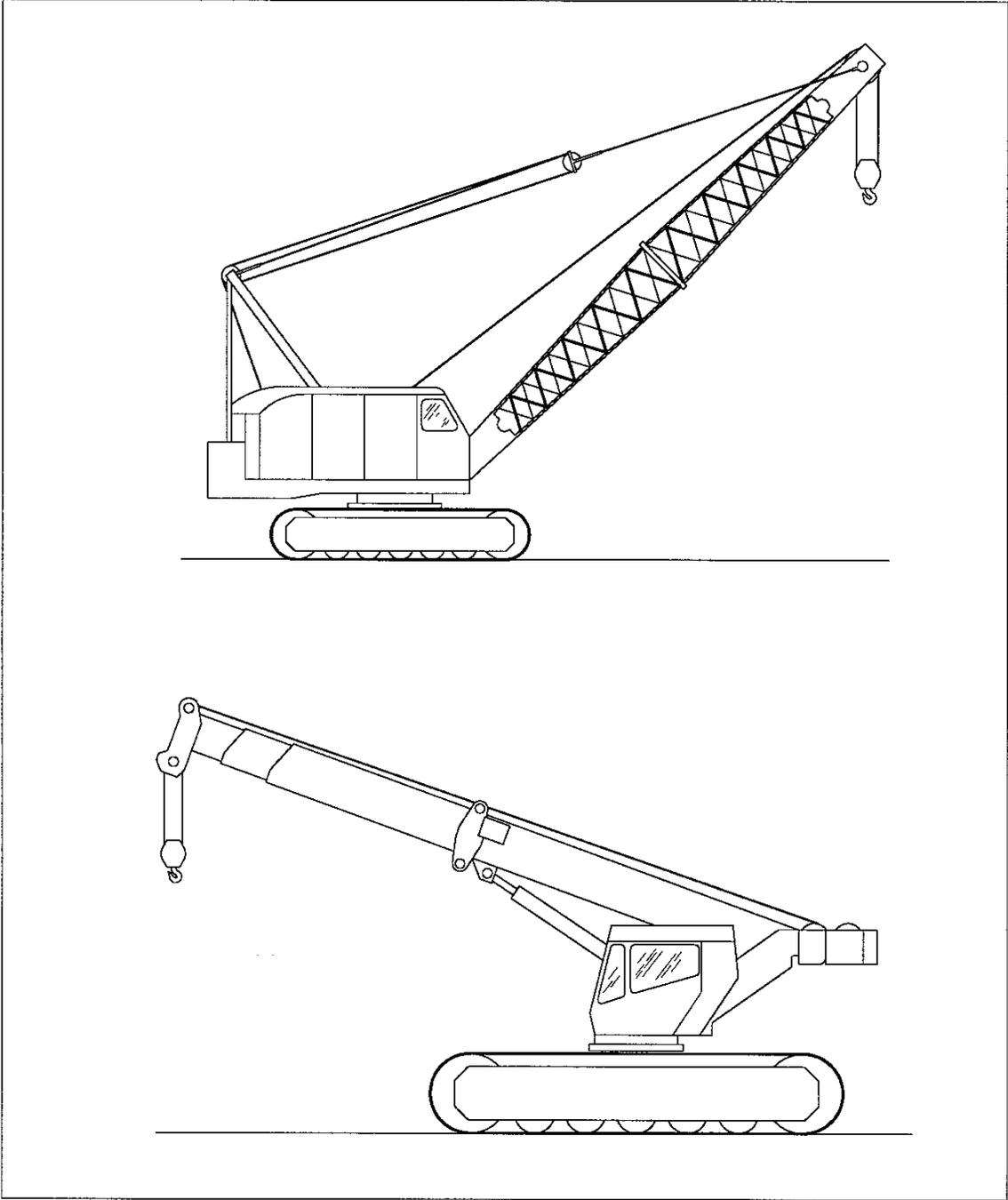


Figure B-18 Mobile Cranes (Track Mounted)



B-1.10.3 Industry Standards. ASME B30.4 prescribes the essential safety standards, safety features, and operational requirements.

ASME B30.5 describes safety standards, safety features and operational requirements for this type of crane with telescoping booms that do not articulate.

ASME B30.22 describes safety standards, safety features and operational requirements for this type of crane when articulated by hydraulic cylinders.

Pedestal cranes, which are intended for offshore service on oil rigs, are designed to comply with API 2C.

Revolving gantry cranes are similar in design to pedestal cranes, but may not comply with API 2C and are not optimized for the marine environment. They are normally installed on traveling gantries (portal bases).

B-1.11 Tower Cranes. Tower cranes are lattice structures with a horizontal boom designed for light loads at high lifts and extended radiuses.

B-1.11.1 General Description. The lattice tower section of a tower crane is capped with a rotating jib and balancing counter jib. The operator's cab is located at the intersection of the tower sections, the jib and the counter jib. Power is normally provided by electrical cable from a ground source.

B-1.11.2 Distinctive Features. The tower crane is typically designed for transportability and rapid erection, although some are designed for permanent installation. Tower sections are joined in segments to achieve the desired hook lift. Jib and counter jib sections are pinned in place and often supported by tension cables. A trolley moves the hook to the desired radius for lifting. The crane base is supported by the first section that is often embedded in a concrete slab designed to resist overturning moment. Tower cranes may also be designed for use on a traveling base.

B-1.11.3 Industry Standards. ASME B30.3 prescribes the essential safety standards, safety features, and operational requirements.

B-1.12 Rubber Tired Gantry Cranes. Rubber tired gantry cranes are designed to provide pick and carry capacity in areas where specific crane runways do not exist. Examples are mobile boat hoists and straddle cranes.

B-1.12.1 General Description. Rubber tired gantry cranes are constructed by joining tubular steel sections in a box frame design. One end of the frame is open in mobile boat lifts to allow the crane to drive over tall vessels. Power is typically provided by an on-board diesel engine and hydraulic pump. The operator's cab is located on one side of the crane near ground level.

B-1.12.2 Distinctive Features. Rubber tired gantry cranes may feature four or more hoists, often with the capability of translating the hoists fore or aftward to adjust to

the load's center of gravity. The crane may be equipped with a spreader beam that provides lift points along the longitudinal centerline of the cranes.

B-1.12.3 Industry Standards. ASME B30.24 describes the essential safety standards, safety features and operational requirements for this type of crane when used in container operations.

ASME B30.2 describes safety standards, safety features and operational requirements for this type of crane when used in hoist/trolley configuration.

B-1.13 Package Hoists. For many top running bridge, under running cranes, and monorail systems, package hoists are the most cost effective option and minimize maintenance. Package hoists are currently available to 50 tons rated capacity and lift heights as high as 75 feet.

B-1.13.1 General Description. A package hoist consists of a wire rope drum with a flange mounted hoist motor, flange mounted speed reducer and flange mounted brake. The hoists may be suspended from trolley or a fixed support by means of a lug, hook, or clevis; bolted directly to a trolley, wall, or ceiling; or form an integral part of a hoist/trolley unit. The trolleys may be plain (hand pulled), geared (hand chain operated through gears or sprockets to the wheels), or motor driven with or without brakes. (Hand chain operated trolleys provide good load spotting ability.) Geared trolleys should be equipped with anti-tilt rollers, which contact the underside of the monorail or bridge beams. These rollers act to balance the eccentric loading applied by the trolley hand chain, preventing excessive tilt of the trolleys.

B-1.13.2 Distinctive Features. Package hoists do not have commercial couplings between components; instead spline couplings are typically used. Individual components are flange mounted (c-face, p-face, etc) and do not require alignment or shimming. The ability for add on features such as additional brakes or limit switches may be limited.

B-1.13.3 Industry Standards. ASME B30.16 describes safety standards, safety features and operational requirements.

The ASME HST series establishes performance requirements for manual, electric and air powered hoists and hoist/trolley units. Electrical and air operated standards include a description of hoist duty service classes. All HST standards include a non-mandatory Appendix A that provides additional design criteria and features for U.S. Department of Defense marine applications as a replacement for MIL-H-15317 (Electric Power Operated Chain and Wire Rope Hoists), MIL-H-904 (Hand Operated Chain Hoists), MIL-H-2813 (Pneumatic Chain and Wire Rope Hoists) and MIL-H-24591 (Pneumatic Trolley Type Chain and Wire Rope Hoists). Non-mandatory Appendix A features are not shown in the technical literature of hoist manufacturers. Individual features such as hazardous material restrictions, ductile material choices and backup hoist operation will require custom design if invoked. The HST standards are:

ASME HST-1, Performance Standard for Electric Chain Hoists.

ASME HST-2, Performance Standard for Hand Chain Manually Operated Chain Hoists.

ASME HST-3, Performance Standard for Manually Lever Operated Chain Hoists.

ASME HST-4, Performance Standard for Overhead Electric Wire Rope Hoists.

ASME HST-5, Performance Standard for Air Chain Hoists.

ASME HST-6, Performance Standard for Air Wire Rope Hoists.

B-2 MISCELLANEOUS BEST PRACTICES.

B-2.1 **Surface Preparation.** The Society for Protective Coatings has developed a series of standards for preparation of structural steel surfaces for proper paint adhesion in the expected service environment. Those standards applicable to cranes include:

SSPC-SP 2; Hand Tool Cleaning
SSPC-SP 5/NACE No. 1; White Metal Blast Cleaning
SSPC-SP 6/NACE No. 3; Commercial Blast Cleaning
SSPC-SP 7/NACE No. 4; Brush-Off Blast Cleaning
SSPC-SP 10/NACE No. 2; Near-White Blast Cleaning

Photographic representations of the required surface finishes are contained in SSPC-VIS 1 and SSPC-VIS 5/NACE VIS 9. Weld spatter is to be removed by hand or power tools prior to blast cleaning.

- (a) Brush-Off Blast Cleaning is adequate for the preparation of faying surfaces of structural connections which are only primed prior to bolting.
- (b) Commercial Blast Cleaning is relatively inexpensive and provides satisfactory surface preparation for many service conditions. Small areas of tightly adhering mill scale may remain.
- (c) Near-White Blast Cleaning removes practically all rust, mill scale, and other detrimental matter from the surface. This level of surface preparation is satisfactory for all but the most severe service conditions.
- (d) White Metal Blast Cleaning removes all traces of rust, mill scale, and all other detrimental matter and defects from the surface. This standard is the most expensive and is justified only for the most

corrosive atmosphere or when special precautions are required to ensure positive paint adhesion.

- (e) Hand Tool Cleaning removes all loose mill scale, loose rust, loose paint, and other loose detrimental foreign matter by hand chipping, scraping, sanding, and wire brushing.
- (f) Completed structural components and weldments blast cleaned to commercial, near-white, or white metal standards, should be primed in the shop. Those that require field welding shall have their welded areas blast cleaned during the erection. In either case, these blast cleaned areas shall be primed before any rusting can occur. The normal practice is to blast clean only as much surface as can be primed the same day.

B-2.2. Test Weights. Cranes designed for handling of items (such as containers) or operating in controlled environments (such as ammunition magazines) should have dedicated test weights for periodic load testing. Cranes operating in ammunition magazines should be provided with compact, purpose-designed test weights to maintain order and neatness in the magazines.

B-2.3 Maximum Wheel Load and Beaming Method (Portal Cranes). The determination of maximum wheel loads of portal cranes involves a statically indeterminate problem. There are several valid methods to obtaining the solution, depending on which simplifying assumptions (such as, condition of the rail system and the portal base structure) are invoked, and the differences between them are not great. The traditional Navy procedure followed for portal cranes is commonly referred to as the "beaming method." The essential element of all these methods is the calculation of the maximum corner load imposed on the portal base by the most adverse loading condition. The maximum corner load occurs when either the boom (with rated load at maximum radius) or the counterweight (with no load on the boom at minimum radius) is approximately at right angles to the diagonal between the adjacent corners. The system of equalizers serves to distribute the corner load equally among all the wheels in each corner of the portal base. The maximum wheel loads calculated by the beaming method are taken as the loads that may not exceed the allowable loads at the assumed spacing for which the rail system was designed.

Secondary effects, such as wind or impact are not included in this value. The inherent rail system design safety margin is understood to be sufficient for tolerating extraneous secondary loads without any degradation of its strength.

The accepted practice in rail system design is to assume 4-foot spacing for the wheels.

B-2.3.1 Beaming Method. The beaming method is described in H.H. Broughton's *Electric Cranes*. It assumes that the weight of the portal base is distributed equally among the four corners (unless there is a significant eccentric load, which can be readily taken into consideration) and that the off-center load from the upper works is

resolved into moment components about the lateral and longitudinal axes. The relative magnitudes of the moment components vary sinusoidally as a function of the orientation of the upper works. The maximum wheel (corner) load is reached when the sum of the two moment components reaches its maximum value.

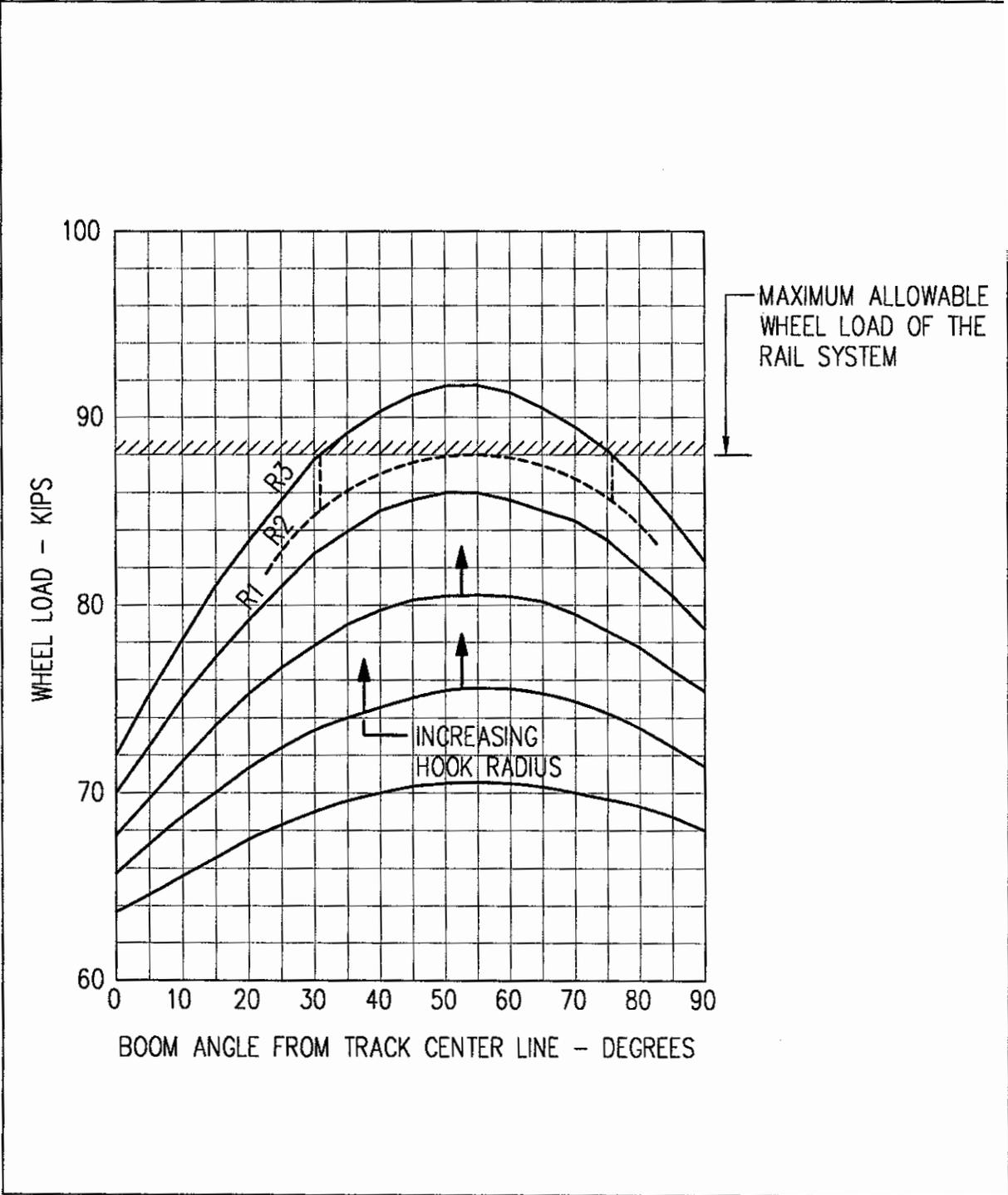
For a square portal base, the maximum wheel load occurs when the boom axis is directly over the corner. For a rectangular portal base, the maximum wheel load is reached when the boom axis is normal (or nearly normal) to the portal base diagonal. Figure B-21 shows in graphic form the variation of the wheel load through one quadrant of rotation as a function of upper works orientation and hook radius (moment) for a typical portal crane with a rectangular portal base. It is important to note that for some radii the maximum allowable wheel load for the rail system is exceeded as the upper works rotates over the corner; and in order to remain within the allowable wheel load, the hook radius shall be reduced (the boom raised) before rotating over the corner. (The dashed line in Figure B-21 shows this path.) If the counterweight is excessive, it may generate the maximum wheel loads when the empty boom is at minimum radius; in which case the boom will have to be lowered to reduce the corner load if the maximum allowable wheel load of the rail system is being exceeded.

The maximum wheel load calculated by the beaming method is used to determine the governing load for the design of the portal base structure and all structural-mechanical components below the main gudgeon connection and the selection of wheel diameter. In the case of older cranes with idler wheel driven travel trucks, the maximum wheel load also governs the design of travel truck gearing, bearings, and axles.

B-2.3.1.1 Formal Presentation of the Beaming Method. The following subparagraphs paraphrase (for consistency of terminology) the description of the beaming method, titled "Truck wheel-pressures under slewing load" from *Electric Cranes*.

Figure B-22 represents the portal base of a portal crane having a main gudgeon spacing "a" and a gauge "b". The portal base (including the travel truck system) weighs " W_G " which weight acts centrally at the point "O", and the upper works, pivoted at "O", and weighing " W_U " has as its center of gravity the point "S" which is a distance "l" from the center of rotation. The angle of inclination of the plane of the boom "OE" with respect to the axis "hf" is " θ ", and the coordinates of the point "S" referred to the two axes "CD" and "BC" are: $x + (a/2)$ and $y + (b/2)$, respectively. To find the load A on crane corner "A" due to the weight of the upper works, first take moments about point "Q" and find $P = W_U\{x + (a/2)\}/a$. (P is the reaction at point "P" due to W_U , if W_U were located at points "S" on an imaginary beam between Points "P" and "Q".) Next take moments about point "B" to obtain load $A = P\{y + (b/2)\}/b$. To this load has to be added $W_G/4$ due to the weight of the portal base. Evidently the load on any crane corner for any angle " θ " can be determined in the same way. Putting $x = l\cos \theta$, and $y = l\sin \theta$, the equations for the several crane corner loads are:

Figure B-19 Variation of Wheel Load Through a Quadrant of Rotation



Equation B-10(A-D) Beaming Method

$$\begin{aligned}
 A &= Wg/4 + Wu/4 \left[1 + (2/\cos \theta)/a \right] \left[1 + (2/\sin \theta)/b \right] \\
 B &= Wg/4 + Wu/4 \left[1 + (2/\cos \theta)/a \right] \left[1 - (2/\sin \theta)/b \right] \\
 C &= Wg/4 + Wu/4 \left[1 - (2/\cos \theta)/a \right] \left[1 - (2/\sin \theta)/b \right] \\
 D &= Wg/4 + Wu/4 \left[1 - (2/\cos \theta)/a \right] \left[1 + (2/\sin \theta)/b \right]
 \end{aligned}$$

The relationship between the load A on crane corner “A” and angle of inclination “ θ ” is shown plotted on polar coordinates in Figure B-23 and from this it will be noted that the load “OP” is a maximum when the boom is at right angles to the diagonal “BD”, that is when $\tan \theta = a/b$. Although the boom directly over main gudgeon “A” is often assumed to give the maximum crane corner load, this is true only when the gudgeon spacing is equal to the gauge. Extending the vector “PO” to “Q” gives “OQ” as the minimum load on crane corner “A” which occurs when the boom is rotated through an angle of 180 degrees from “OP” to “OP₁”.

B-2.3.2 Other Methods. Other methods than the Beaming method may provide results that are not proven or do not take into account the actual condition of the Navy’s portal crane rails. For example, the moment of inertia method assumes the crane rails to be perfectly level and rigidly supported. The moment of inertia method yields maximum wheel load that are about 8 to 10 percent lower than those obtained by the beaming method. Since the actual condition of crane rails does not justify such assumptions, this method of determining the maximum wheel loads is not used in the design of Navy portal cranes. Methods of determining maximum wheel loads other than the beaming method may be used only with Navy Crane Center approval

Figure B-20 Beaming Method Model

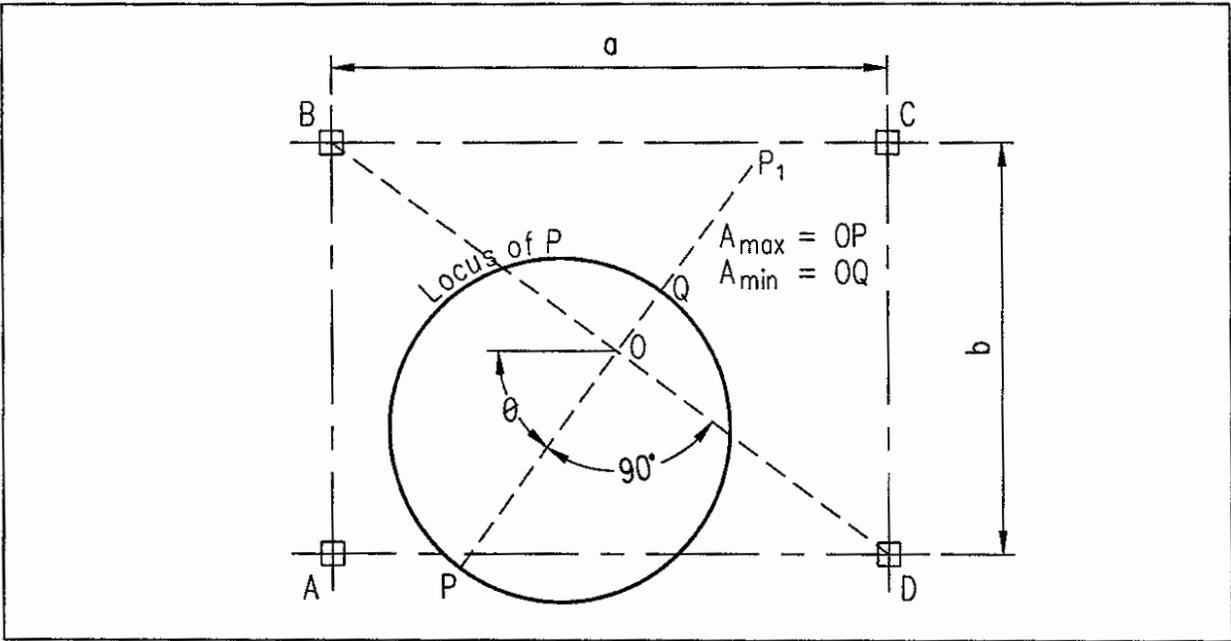
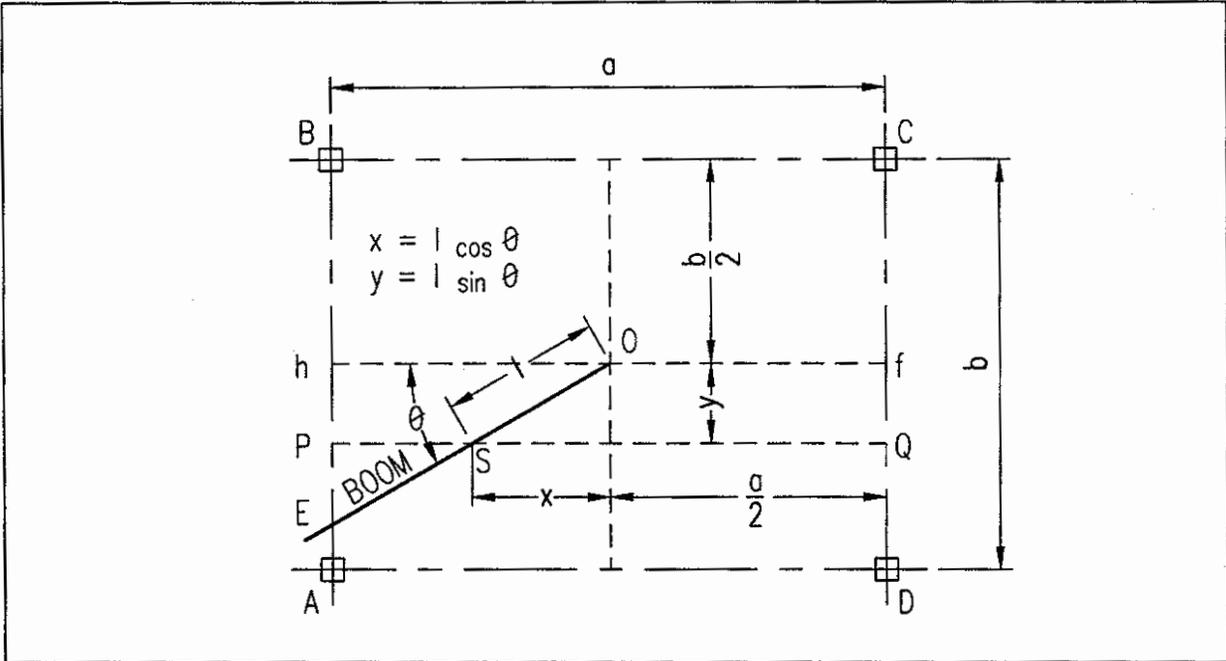


Figure B-21 Relative Variation of Corner Load During Full Rotation

B-2.4 Travel Truck Float. The need to negotiate sharp turns around heads of drydocks introduces distortions to the steering/travel geometry of the travel truck system that can be accommodated only by a unique design feature commonly referred to as “float”. The amount of float is determined by combining the geometric effects of increased effective gauge between opposite travel trucks on the curve (because their straight-track common axis pivots with respect to the radius of the curve) and the different “heights” of the opposite circular segments of travel truck frames and equalizers on the inner and outer rail curvatures. Figure B-22 demonstrates these effects graphically for a 32-wheel portal crane.

B-2.4.1 Float Pin/Bushing Assemblies. These assemblies are exceptionally sensitive to design details for proper operation. They are subjected to severe bending moments with edge loading on the bushings and exposure to the weather. The friction forces developed on their sliding surfaces determine the magnitude of the lateral (spreading/squeezing) loads and moments that are imposed on the entire travel truck system and the portal base structure. One means of minimizing such loads is to locate the float pins at the lowest level – in the travel truck frames. It is also critical that the friction coefficient be maintained at the design value.

B-2.4.1.1 Float Pins. Float pins have longer unsupported spans than rocker pins and are expected to have noticeable deflection (bowing) under load. There is no particular limit on deflection, and in practice the pin diameter is defined by the float bushing design considerations.

B-2.4.1.2 Float Bushings. The eccentric loading due to float and travel wheel flange-to-rail clearance and the lateral spreading/squeezing forces, cause moment loads that either increase or decrease the nominal bearing pressure on the float bushing bores. The bearing stress distribution is further influenced by edge loading that develops at the end of the bushings. The combining effects of these stresses and influences on a typical float pin/bushing assembly are represented graphically in figure B-25.

The expected deflection of the float pin, although not usually calculated, is taken into account by providing a generous bore-to-pin clearance of 2.0 to 3.0 times that of the medium running fits (RC5 or RC6 of ANSI B4.1) for the same diameter.

Figure B-22 Portal Crane Truck Float

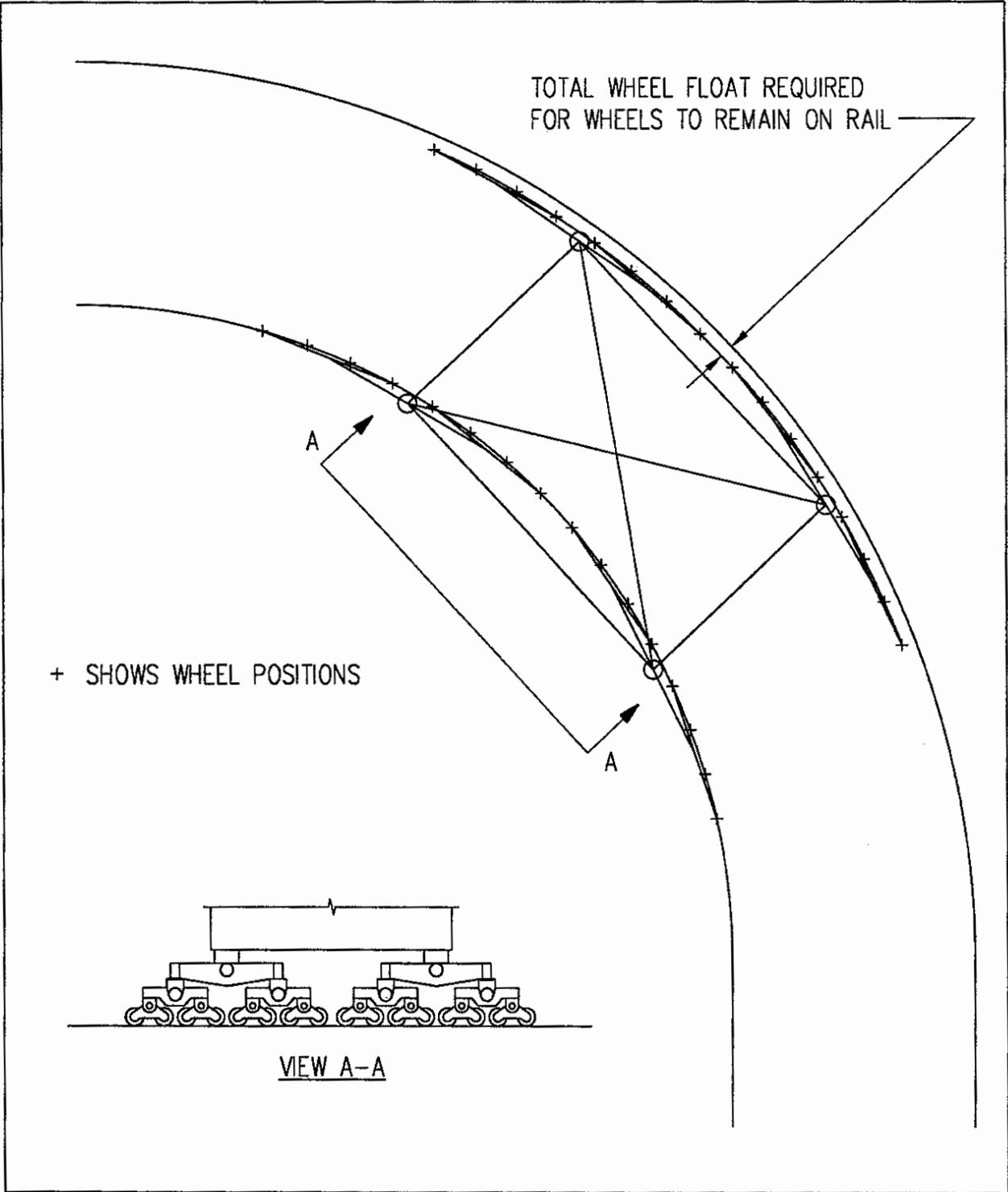
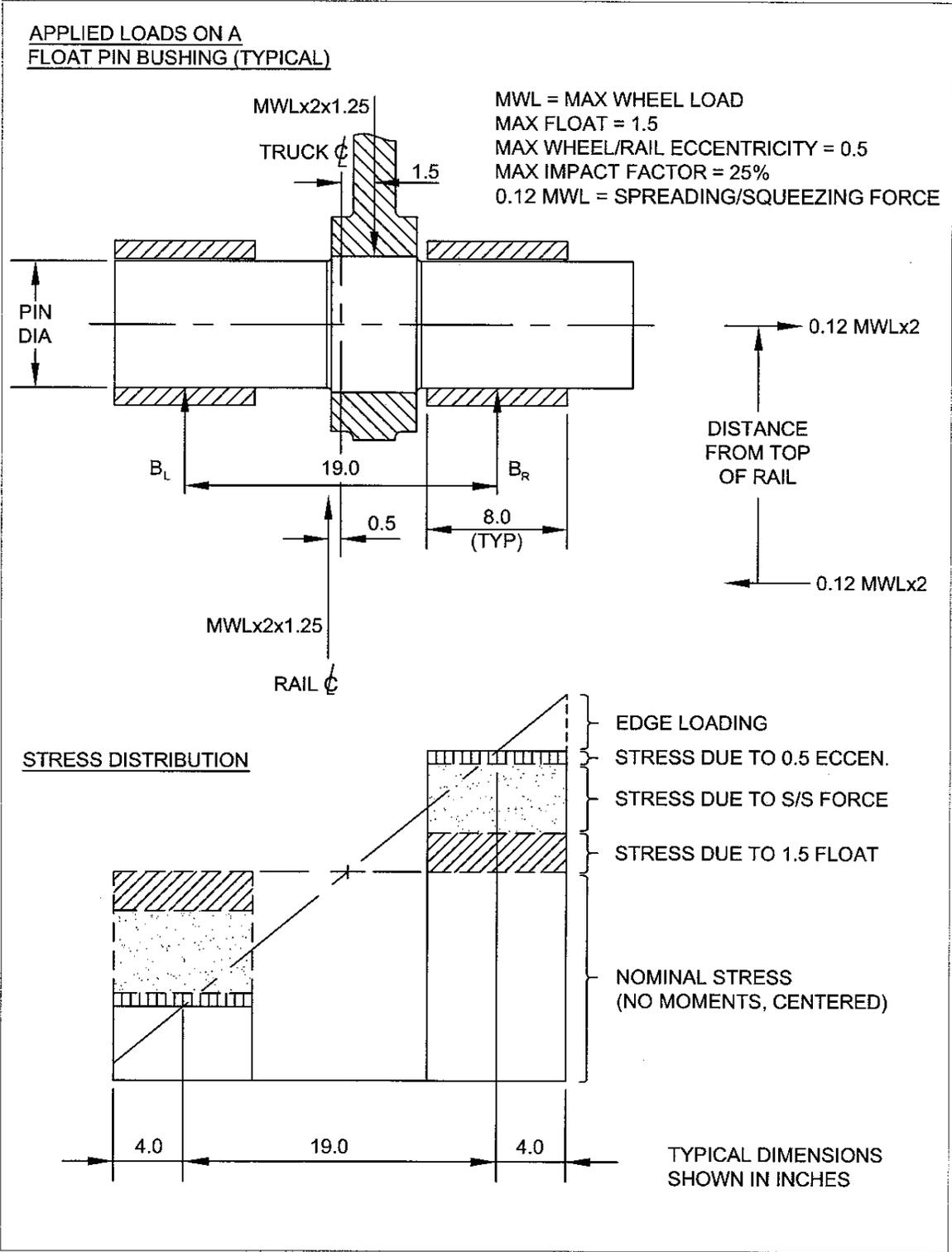


Figure B-23 Cross Section of Assembly (At Maximum Float)



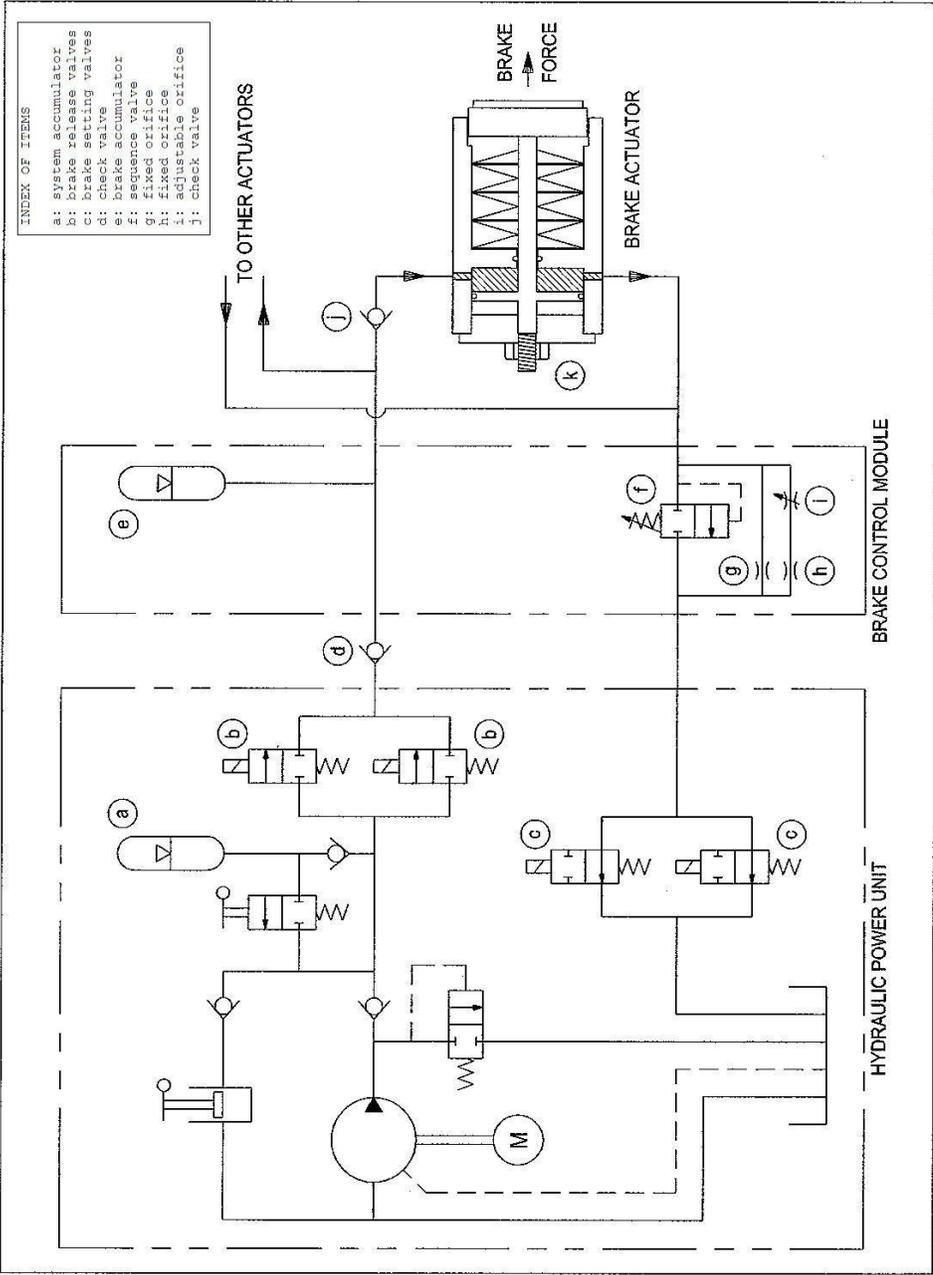
B-2.5 Emergency Hoist Drum Brake System. SPS portal cranes, ordnance handling container cranes, and other cranes, when specified, are equipped with emergency caliper disc brakes on the hoist wire rope drum flanges. These brakes are spring-set/hydraulically-released for an emergency stop, and are also arranged to set automatically in case of hoist loss of power or drive train failure. A dedicated hydraulic system is provided for the operation of these brakes on the hoist(s). On some cranes, these brakes also serve as secondary, brakes although experience has shown that this is not recommended; they operate more reliably as tertiary brakes and are activated only by loss of power, detection of a drive train failure, emergency stop, or crane shutdown. When activated, the brake application process is controlled to avoid causing an impact greater than that used in the design load cases for the boom and other components. Furthermore, the brake setting sequence and timing with respect to other brakes on the hoist are coordinated to avoid drive train torque lock-in, described in paragraphs 2-3.22.2 and B-2.5.3 (Caliper Disc Brakes) of this instruction. Interlocks with the control system are provided to preclude operation of the hoist(s) if the system pressure is below the minimum required level. The brake system includes the hydraulic power unit, electronic failure detection system (commonly called "broken shaft detection system" or BSDS), brake control module, and brake actuator(s). The basic hydraulic elements of the system, except BSDS, are shown in figure B-24.

B-2.5.1 Hydraulic Power Unit. The hydraulic system is independently powered by an electric motor and is comprised of the main components shown in figure B-35. (Various ancillary components - check valves, friction surface burnishing/ conditioning valve, filters, pressure switches, etc. are omitted for clarity.) The hydraulic pressure required to release the brakes is developed by the pump and stored in the system accumulator (item a). When the diesel engine-generator set is started and the main line contactor is energized, pressure switches automatically energize the electric motor to pressurize the hydraulic system to maintain the system accumulator pressure within the prescribed range. Critical solenoid brake release valves (items b), and brake setting valves (items c), are arranged in parallel for maximum reliability. The brakes are released when the brake release valves (items b) are opened and the brake setting valves (items c) are closed. (The system accumulator is sized to provide several brake release cycles in case of power loss.) The brakes remain released as long as the brake setting valves (items c) are in the closed position and the system pressure is maintained. For the brakes to set the brake setting valves (items c) shall open and the brake release valves (items b) shall close, allowing the hydraulic fluid to be forced out of the brake actuator by the spring pack. Check valve (item d) blocks fluid backflow from the brake accumulator (item e). The hand pump is provided to serve as a back-up for the powered pump to gradually release the brakes and lower the load in case of power failure and to release the brakes for maintenance work without energizing the normal power source.

B-2.5.2 Failure Detection System (BSDS). Generally, the relative displacement angle between the hoist drive gear and the wire rope drum shaft is monitored by encoders. When these two quantities differ by more than a pre-determined amount, the PLC, or other circuitry, determines that a drive train discontinuity (mechanical failure) has occurred and the brake setting sequence is initiated. Concurrently, the hoist drive motor is de-energized. A control algorithm or other physical means is used to filter the

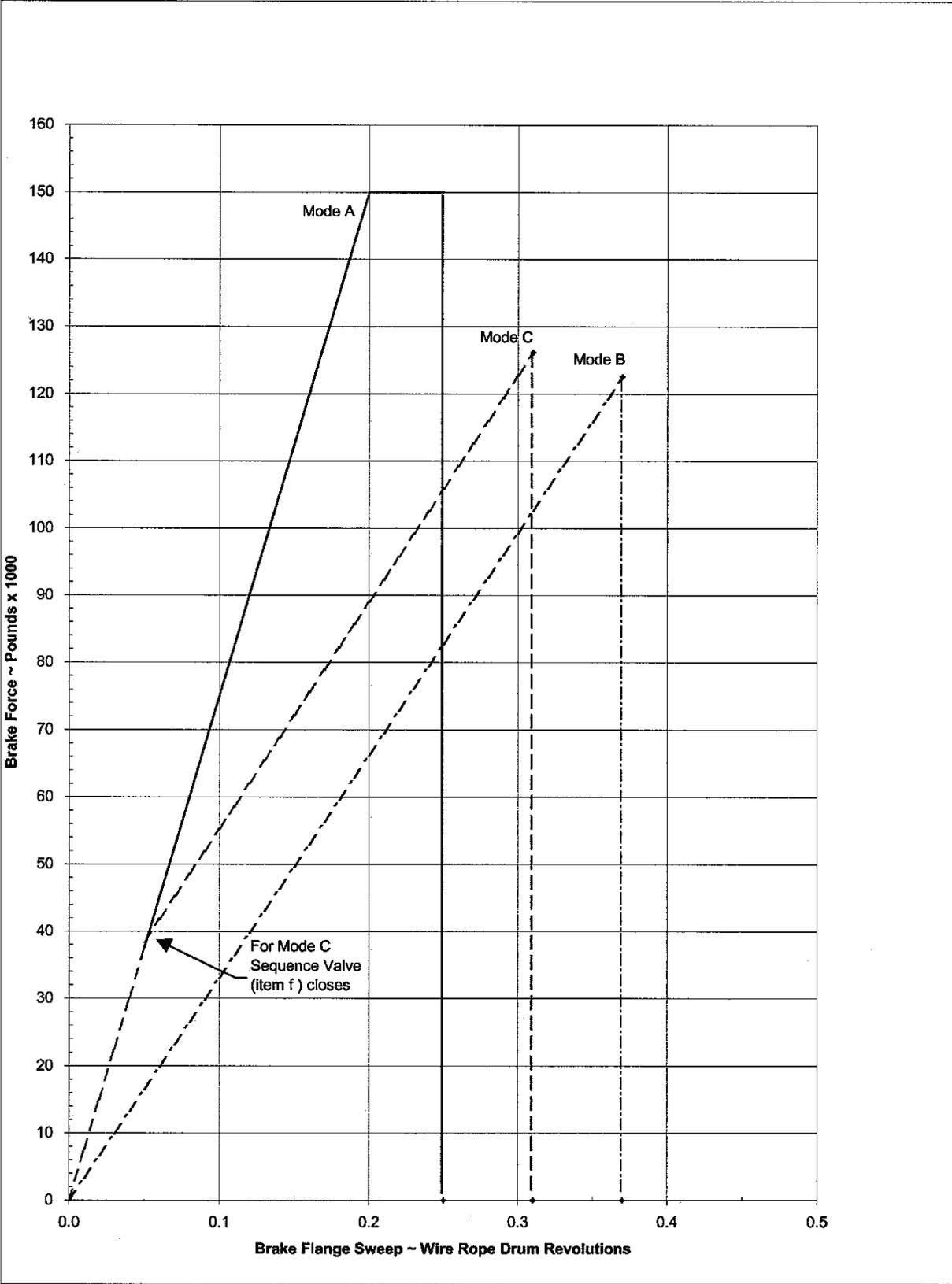
encoder signals to discount any false failure indications that may be caused by gearing backlash or dithering. Test switches are provided to test the operation of the failure detection system by disrupting the encoder signal or interrupting the power to the encoder. Alternatively, on some designs only an overspeed condition of the hoist drum is monitored. This is not acceptable for SPS applications.

Figure B-24 Emergency Hoist Brake Circuit (Open Loop, Closed Center)



EMERGENCY HOIST BRAKE CIRCUIT (OPEN LOOP, CLOSED CENTER)

Figure B-25 Brake Setting Modes



B-2.5.3 Brake Control Module. On SPS portal cranes the module consists of the brake accumulator (item e), sequence valve (item f), two fixed orifices (items g and h), and an adjustable orifice (item i). The brake setting sequence is initiated when solenoid valves (items b and c) are de-energized; that is, brake release valves (items b) are closed and brake setting valves (items c) are opened. As long as the brake accumulator (item e) pressure between the brake release valves (items b) and the sequence valve (item f) is higher than the spring setting of the sequence valve (item f), it will remain open and permit free flow of fluid to the reservoir. The fluid will continue to drain from the brake actuator and the hydraulic lines until the pressure falls to the level at which the sequence valve (item f) closes. At that point the air gap between the brake actuator friction pad and the brake rotor is closed, and the initial (reduced) brake force is applied. With the sequence valve (item f) closed, the fluid can drain only through the orifices (items g, h, and i), and the brake force - the difference between the spring pack and the fluid pressure resisting it - is progressively ramped up to its maximum value. Check valve (item j), located as close to the brake actuator as practical, serves to preclude sudden fluid escape and rapid application of the maximum brake force in case of rupture in the high pressure portion of the brake system. The adjustable orifice (item i), in conjunction with the parallel fixed orifice (item g), is set to provide the desired brake setting ramp rate. Fixed orifice (item g) is sized for the slowest acceptable brake setting rate (minimum flow) as a precaution against inadvertent full closure of the adjustable orifice (item i). The fixed orifice (item h), in series with the adjustable orifice (item i), is a similar precaution against inadvertent full opening of adjustable orifice (item i) to limit the fastest acceptable brake setting rate (maximum flow). During the subsequent brake release, fresh fluid is pumped into the brake actuator.

On container cranes, the brake control module (unlike that shown in figure B-24) consists of only one fixed orifice installed downstream of the brake actuator to provide time delay for the drive train rotational inertia to dissipate before the brake sets. On some container crane hoists, however, the required time delay cannot be provided because of excessive load or boom drift, and all rotational inertia torque cannot be dissipated. In those cases, it is necessary to add an orifice upstream of the brake actuator to slow down the release of the brake and allow the locked-in torque to be relieved gradually, avoiding the sudden release of strain energy and gear tooth impact. Alternatively, the hydraulic power unit may be arranged to hold the brake release valves (items b) open while the system is being initially pressurized to gradually release the brake and any locked-in torque.

The brake application process shall also avoid causing an impact greater than that used in the design load cases for the hoist drive train, boom, and adjacent mechanical and structural components. To obtain a satisfactory compromise between these conflicting requirements - no lock-in of drive torque, the quickest stop, and impact limited to the mechanical and structural design load cases - brake application shall follow a defined process. Figure B-25 presents in idealized graphic form three representative brake setting modes, each absorbing the same amount of energy to bring the hoist to a full stop. In each mode, a satisfactory compromise between conflicting requirements shall be obtained for the specific application.

1. Mode A is an unrestricted process - the hydraulic fluid holding the brake in the released position is dumped directly into the reservoir and the brake force increases rapidly to its maximum level of 150% of the rated hoist load torque (maximum brake force), imposing the maximum impact on the structural and mechanical components. After the braking force reaches its maximum level, the drive motion continues until all the energy of the hoist is absorbed by the brakes. Hoist motion is stopped in the shortest time and the shortest sweep of the brake flange through the brake friction pads. This mode may be used on Navy cranes as a secondary brake, but shall be time-delayed to preclude torque lock-in.
2. Mode B is a relatively slow brake setting process because the draining of hydraulic fluid is restricted by the orifice. It requires more time to stop the hoist but absorbs all the resultant energy with a lower impact than Mode A. Mode B is used on some Navy ordnance handling container cranes where the brake is a secondary brake. For some operating conditions, however, the stopping time may be too long and load drift excessive, and ramping (Mode C) may be required.
3. Mode C is a combination of the performance characteristics of Modes A and B - the initial phase is that of Mode A and the final phase of Mode B. As shown in figure B-25, Mode C stops the motion with a shorter flange sweep and in shorter time than Mode B, and maintains approximately the same maximum impact (brake force). This mode is used on SPS portal cranes.

B-2.5.4 Brake Maintenance Provisions. Consistent brake performance is sensitive to the condition of the brake friction surfaces. Since the entire brake flange in this brake application is rarely pulled through the friction pads to clean off any accumulated corrosion, a low pressure hydraulic circuit (not shown in figure B-24) is normally provided to periodically condition the friction surfaces. Furthermore, a manual release nut (item k) is installed on the end of the actuator piston stem to hold the brake in the released position (without hydraulic pressure) when required for hoist maintenance.

B-2.6 Radio Controls. Navy Crane Center previously recommended the use of licensed frequencies for all radio equipment. However, in recent years the safety and reliability of unlicensed radio systems has been proven at numerous activities. This coupled with the safety features that manufacturers have been required to build into their systems through documents like the ANSI ECMA 15 has led Navy Crane Center to recommend unlicensed systems due to ease of setup and performance. Typically these unlicensed systems operated in the 430 MHZ or 900 MHZ spectrum.

The range of licensed portable transmitters operating on Government exclusive and Government shared frequencies is less than 1000 feet. In the past, Navy activities obtained dedicated Government "mobile band" frequencies between 30 to 50

megahertz and 73 to 76 megahertz. Now portable transmitters may operate on either Government exclusive or Government shared frequencies.

Completed Form DD1494 shall be mailed with cover letter to Naval Electromagnetic Spectrum Center (NAVEMSCEN), 2461 Eisenhower Avenue, Hoffman I Suite 1202, Alexandria, VA 22331-1400. For licensed systems, NAVEMSCEN is responsible for reviewing the forms and providing a status report to CNO/N6. A copy of the cover letter without Form DD1494 shall be mailed to Chief of Naval Operations (CNO), Director of Space, Information Warfare, Command and Control, Attn: CNO N61F, 200 Navy Pentagon, Washington, DC 20350-2000. CNO/N6 will return a letter identifying approval or non-approval of forms to the originating organization in three to four months. After approval of Form DD1494, the local frequency coordinator shall be consulted to assign a Government exclusive or Government shared frequency that will not cause interference problems with other transmitters and receivers. A new on-line system for Equipment Location-Certification Information Database (EL CID) is being setup to accept frequency allocation forms and eventually the paper DD1494 form may not be accepted.

GLOSSARY

Terms

Actuator – Pneumatic, hydraulic, and electric (solenoid) actuators are standard commercial assemblies used to operate mechanisms such as spud locks and boom hoist pawls, monorail track interlocks, and twist locks on container crane spreaders. Each type is designed and constructed according to the applicable industry standards. The output motion of the actuator may be linear or rotational. Actuators operate or engage load bearing components of cranes but are not themselves load bearing.

Armature – The power-producing component of a motor. The armature can be on either the rotor or the stator.

Ballast – Material added to the lower or non-rotating portion of the crane (or barge) to aid in the overall stability of the crane (contrast with counterweight)

Bent Rail Roller Path – A roller path consisting of bent rail segments that are spliced at the webs with two or three bolts per side and have their bottom flanges secured to the support structure either with standard rail clips fastened with through bolts or welded threaded studs.

Bonded (Bonding) – Connected (connecting) to establish electrical continuity and conductivity to establish an effective path for fault current that, in turn, facilitates the operation of the overcurrent protective device.

Brinell Scale – The Brinell scale characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test-piece. It is one of several definitions of hardness in materials science.

Bushing (Plain Bearing) – Typically a copper alloy (brass or bronze) sleeve, which is pressed into the bores of mechanical components to allow slow oscillating rotation, or “dithering motion”, of steel shafts or pins.

Caliper Disc Brakes – Brakes that apply the braking force to both sides of the brake rotor - either in the form of a disk mounted on the high speed shaft of the speed reducer or motor or a flange mounted on the shell of the wire rope drum.

Carrier Yokes – See figure 2-4. Designs (d), (e), and (f) are either ductile or malleable cast iron type. Designs (e) and (f) may include side guide rollers, in which case the wheels are flangeless. All wheel axles are fixed (non-rotating) and some wheel bearings are retained with snap rings. The bottom of the carrier yoke has a seat for a swivel washer to equalize the wheel loads and allow the wheels to turn on curves.

Cast Rail Roller Path – Cast rail roller paths, the bull gear may be separate or integral with the rail segments.

Characteristic Impedance – Characteristic impedance is the ratio of the amplitudes of a single pair of voltage and current waves propagating along the line in the absence of reflections.

Closed Loop System – A closed loop system is a drive system where there is motor shaft speed feedback to the drive controller by a tachometer-generator, encoder, or resolver.

Collector Ring Assembly – Transmits electric power and communications signals from the upper rotating portion of a crane to the lower non-rotating portion of a crane and vice-versa.

Combination Hydraulic Shoe Brakes – Mechanical-electrical shoe brake equipped with a hydraulic activating system.

Connecting Bars – See “Load Bars”

Contactors – A contactor is a magnetically-operated device, for repeatedly establishing and interrupting an electrical power circuit.

Counterweight – Material added to the upper or rotating portion of a crane to assist in the stability of the rotating portion of the crane (contrast with ballast).

Definite Purpose Contactors – A contactors that has a rating assigned to it by the manufacturer based upon relatively low duty cycles.

Disc Brakes – A brake that uses several alternating stationary and rotating discs (pressure plates and friction discs) to develop a high friction (braking) force from the pressure of a number of symmetrically arranged coil springs. Discs are free to slide axially – the stationary set inside the housing (usually on pins) and the rotating set on the spline of the drive shaft.

Drive Heads – An arrangement similar to a carrier yoke but equipped with an electric motor and a set of gears to drive the wheels.

Eddy Current Brakes – An eddy-current brake provides a supplemental load on the motor and causes the motor to rotate at a slower speed than it would due only to the load under the hook. Eddy current brakes can be used for speed control and emergency braking.

Electro-Hydraulic (Thruster) Brakes – Similar in arrangement to an electro-mechanical shoe brake, except that an integral hydraulic unit (electric motor, pump, and piston/cylinder) is used to provide the operating force.

Encoder – Device coupled to motor shaft to provide speed and shaft position; typically used on hoist drive in closed loop configurations. Typically, encoders are of the quadrature type, that is, that they utilize two output waves 90 degrees out of phase.

Equipment Grounding Conductor – The conductor installed to connect normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor. Note: It is recognized that the equipment grounding conductor also performs bonding.

Exposed (as applied to live/energized parts) – Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to parts that are not suitably guarded, isolated, or insulated.

Festoon Type Electrification System – An electrification system consisting of cables suspended from carriers riding on an I-beam or similar support.

Field Weakening – Reduction in field voltage which results in faster motor speed and reduced motor torque.

Field Winding – The conductors wound into the slots around electromagnetic material that creates a magnetic field when energized.

Fleet Angle – The angle that the wire rope, at its point of tangency, forms with the groove of the sheave or the drum. The helix angle of the wire rope grooves is usually very small and may be omitted in calculating the fleet angle.

Fleeting Sheave Pin – A long stationary pin that is commonly mounted in the legs of the A-frame to support the fleeting sheaves which slowly rotate and slide on bushings along the pin.

Float Pin – The gudgeon pin of travel trucks that operate on curved track and provide for lateral sliding (floating) of the travel truck

Gearmotor – A speed reducer and motor packaged into a single unit. Gearmotors are usually commercial off-the-shelf products.

Grain Size Number – The grain size number is based on the number of grains per square inch at a magnification of 100X. The grain size is a measurement of material microstructure homogeneity.

Ground – The earth.

Ground faults – A line-to-ground fault.

Grounded (Grounding) – Connected (connecting) to ground or to a conductive body that extends the ground connection.

Grounding Conductor – A conductor used to connect equipment or the grounded circuit or a wiring system to a grounding electrode or electrodes.

Grounding Electrode – A conducting object through which a direct connection to earth is established.

Grounding Electrode Conductor – A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.

Gudgeon – Vertical stem of gudgeon assembly.

Gudgeon Pin – Horizontal pin of gudgeon assembly.

Gudgeon Assembly – Intermediate members between different levels of equalizers in a travel truck system or between equalizers and travel trucks to allow them to swivel and follow the curvature of the rails.

Horizontal Side Load – A combination of the acceleration forces due to rotate motion, and the sidelead force due to the maximum list and trim for floating cranes.

Hotel Power – Power used to energize cranes' ancillary systems, such as lights and heaters, during prolonged periods of inactivity.

Impact – The vertical dynamic force on the lifted load due to handling.

Incident Wave – The initial wave that propagates down the line during energization of an electrical circuit (i.e. motor starting).

Isolation Transformer – A transformer designed to provide electrical isolation (decouple) between two circuits.

Keeper Bar/Plate – A bar used to provide positive means to prevent a pin from backing out and rotating (or in some designs, backing out only) after installation.

Key – A demountable machinery part which, when assembled into a keyseat and keyway, provides a positive means for transmitting torque between the shaft and hub.

Keyseat – An axially located rectangular groove milled into a shaft. ASME B17.1 does not differentiate between a keyseat and a keyway.

Keyway – An axially located rectangular groove broached into a hub. ASME B17.1 does not differentiate between a keyseat and a keyway.

Limit Switch – Supplementary devices used to establish the limits for movement of a crane drive.

Load Bank – A set of power resistors used to absorb regenerative power from motors to prevent back-driving (over-speeding) the diesel engine-generator set.

Load Bar – A standard commercial items made by the manufacturers of the carrier yokes and drive heads to match their products and connect end trucks to bridge structure.

Load Girt – A beam that provides lateral support to the hoist upper block sheaves in a trolley side frame.

Metal Oxide Varistor (MOV or Surge-Suppressor) – A discrete electronic component that diverts excessive voltage to the ground and/or neutral lines.

Mechanical Load Brake – A type of automatic unidirectional friction brake that only supplies braking force in the lowering direction. In the hoisting direction the assembly does not supply braking force. Usually activated by a pawl and ratchet or roller ratchet. Used for moderate lifting heights and typically in package hoists (but previously in speed reducers and may still be available in a limited number of reducers but not as a separate unit).

Microprocessor Drive – A generic term for a drive, either AC or DC that primarily uses electronics instead of contactors and relays to control the motion of motors. This term encompasses digital DC and variable frequency AC of both closed and open loop designs

Motor Branch Circuit – A circuit that supplies power to one or more motors and their associated controllers or control circuits.

Mounted Bearings – Bearings of all types that are available in housings designed for bolting to support structures.

Non-operating Wind Load – The wind force derived from the maximum gust velocity at a location.

Offlead Angle – The angle between the vertical axis of the crane and the true vertical axis, in the direction parallel to the hook radius.

Offlead Force – The resulting component of force from the offlead angle.

Open Loop System – A drive system where there is no motor shaft speed feedback to the drive controller.

Operating Wind Load – The wind force derived from the maximum wind speed where continued operation is permitted and which is combined with other operating loads in crane design.

Overhaul Weight – The load block weight required to ensure an unloaded hook will lower.

Overhauling Load – A load that attains a speed greater than that of the motor speed-load characteristic and under which the load tends to drive the motor.

Pendant Pushbutton Station - A device suspended from the crane to enable operation of the crane from the floor or other remote location.

Plugging – Reversing the motor's operating direction to serve as a motor brake.

Point of Common Coupling (PCC)– The point at which the electric utility and the customer interface occurs. Typically, this point is the customer side of the utility revenue meter.

Raceway – An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or busbars. Raceways include, but are not limited to, rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquidtight flexible conduit, flexible metallic tubing, flexible metal conduit, electrical nonmetallic tubing, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busbays.

Rated Load – The maximum rated capacity of the hoist or crane.

Rectifier – A circuit that converts an AC signal into a unidirectional signal (i.e. a type of DC-AC converter) that depending on the input signal is classified into two types: single phase and three phase.

Reeve (Reeving) – The pattern of threaded rope over sheaves and drums, or the act of threading a rope over sheaves and drums.

Reeving Arrangement/Diagram – A plan showing the path that a rope takes as it is routed through all sheaves and drums of a piece of equipment.

Reflection Coefficient – This describes either the amplitude or the intensity of a reflected wave relative to an incident wave.

Relays – An electrically controlled device that opens and closes electrical contacts to effect the operation of other devices in the same or another circuit.

Reservoir – A tank that provides a source of make-up fluid for cylinder extension or system internal leakage; lets the fluid cool and de-aerate; and allows the contaminants to settle to the bottom.

Rigid Conductor Bar System – A system consisting of a spring applied sliding pickup collector which travels on a conductor bar to provide power to a crane.

Rockwell C-scale (HRC) – A method for testing a material's hardness that uses an indenter to test the material's resistance to deformation as a load is applied.

Roller Path – The roller path assembly includes the upper and lower rail circles, bull gear, rollers, and the roller cage.

Rotate Holding Brakes – A brake system that may take the place of a spud lock. These brakes are in the form of low ratio speed reducers (installed to be back driven and act as speed increasers) with a brake on the high speed (low torque) shaft and a

pinion in mesh with the rotate bull gear on the low speed (high torque) shaft. The holding brakes allow the crane to be stowed with the boom in any direction and there is no possibility of accidental damage due to unintentional activation.

Sheave Nest – An assembly at the top of the A-frame or boom area that holds multiple sheaves.

Shoe Brakes – A brake consisting of two external shoes, with riveted or bonded friction linings, that act on the outside diameter of a brake wheel.

Shore Power – Power used to operate portal, floating, and container cranes in case of loss of their on-board diesel engine-generator power sources.

Sidelead Angle – The angle between the vertical axis of the crane and the true vertical axis, in the direction perpendicular to the hook radius.

Sidelead Force – The resulting component of force from the sidelead angle.

Slewing Ring Bearing (Rotate Bearing) – A precision assembly of rings (races), rolling elements (balls or rollers), and separators, which allow a cranes upper works to rotate separate from the cranes lower works without the need for a balanced deck design.

Slip Ring – An assembly that enables making an electrical connection through a rotating assembly.

Spreading and Squeezing Forces – The friction forces due to the outward or inward movement when a portal crane travels into a curve. When this happens, the effective gauge of the rail changes and the travel trucks slide on their float bushings.

Spud Lock – An assembly consisting of a pin and socket that positively secures the crane's upper works against rotation during periods of inactivity.

Standing Wave (Reflected Wave) – The resultant wave propagation that occurs when the incident wave is reflected off a discontinuity in the line (i.e. motor terminals) that is superimposed on the incident wave.

Step-Down Transformer – A transformer designed to change the power system voltage to a lower voltage.

Strut – A structural frame that controls the movements of the boom and supports the outboard luffing hoist sheave nest and hoist deflector sheaves. It pivots on hinges similar to those of the boom, and is connected to the boom by means of wire rope pendants. Also known as a floating mast.

Thyristors – A family of power semiconductor devices used extensively in power electronic circuits as bistable switches operating from nonconducting state to conducting state.

Transformer – A static device comprised of a winding, or two or more coupled windings for introducing mutual coupling between electric circuits. It is designed to allow for the transfer of electrical energy from one circuit to another circuit.

Transients and Harmonics – Distortions to the incoming power feeding electrical equipment. These distortions may be standing waves, reflected voltages, or other phenomena. These phenomena may occur on all types of control systems.

Tub Structure – The circular structure in the barge of a floating crane on which the crane is mounted and supported.

Under-voltage “UV” relay – A relay used in the control circuit to ensure that the line-to-line voltage is suitable.

Variable Frequency Drive – A system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor. This term includes both closed loop and open loop AC drives.

Wheel Base – For four wheel cranes, the center-to-center distance between the wheel axles. For eight-wheel cranes, the center-to-center distance between the outermost wheel axles.

Acronyms

AC – alternating current

AISC – American Institute of Steel Construction

ANSI – American National Standards Institute

ASME – American Society of Mechanical Engineers

ASTM – American Society for Testing and Materials

BHN – Brinell Hardness Number

CAR – crane alteration request

CFR – Code of Federal Regulations

CMAA – Crane Manufacturers Association of America, Inc.

CNO – Chief of Naval Operations

DC – direct current

GPS – general purpose service

HRS (Rc) – hardness Rockwell C-scale

IBC – International Building Code

ICS – Industrial Control Systems

I_p – importance factor

MOV – metal oxide varistor

mph – miles per hour

NAVEMSCEN – Naval Electromagnetic Spectrum Center

NAVFAC – Naval Facilities Engineering Command

NEC – National Electric Code

NEMA – National Electrical Manufacturers Association

NFPA – National Fire Protection Agency

PCC – point of common coupling

PPM – parts per million

psf – pounds per square foot

psi – pounds per square inch

SAE – Society of Automotive Engineers

SPS – special purpose service

UL – Underwriters Laboratories

VAC – volts (alternating current)

VDC – volts (direct current)

VFD – variable frequency drive

DESIGN OF NAVY SHORE WEIGHT HANDLING EQUIPMENT