Specification for Offshore Pedestal Mounted Cranes

API SPECIFICATION 2C
SIXTH EDITION, MARCH 2004

EFFECTIVE DATE: SEPTEMBER 2004

American
Petroleum
Institute

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Upstream Segment

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FOREWORD

This specification is under the jurisdiction of the API Subcommittee on Standardization of Offshore Structures.

The purpose of this specification is to provide standards for offshore pedestal mounted cranes suitable for use in drilling and production operations.

This standard shall become effective on the date printed on the cover but may be used voluntarily from the date of distribution.

This edition of API Spec 2C supercedes the Fifth Edition dated April 1995. The number and nature of changes in this edition from the previous edition are such that marking the changes between the two editions is impractical.

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Specification for Offshore Pedestal Mounted Cranes

1 Scope

1.1 GENERAL

This specification details the requirements for design, construction, and testing of offshore pedestal mounted cranes. Offshore cranes are defined herein as pedestal mounted elevating and rotating lift devices of the types illustrated in Figure 1 for transfer of materials or personnel to or from marine vessels and structures. Offshore cranes are typically mounted on a fixed (bottom supported) or floating platform structure used in drilling and production operations. API Spec 2C is not intended to be used for the design, fabrication, and testing of davits and/or emergency escape devices. API Spec 2C is also not intended to be used for shipboard cranes or heavy lift cranes. Shipboard cranes are mounted on surface type vessels and are used to move cargo, containers, and other materials while the crane is within a harbor or sheltered area. Heavy lift cranes are mounted on barges or other vessels and are used in construction and salvage operations within a harbor or sheltered area or in very mild offshore environmental conditions.

1.2 SAFE WORKING LIMITS

The intent of this specification is to establish safe working limits for the crane in anticipated operations and conditions. This is accomplished by establishing Safe Working Loads (SWLs) based on allowable unit stresses and design factors. Operation of the crane outside of the limits established by the manufacturer in accordance with the guidelines set forth in this document can result in catastrophic failure up to and including separating the entire crane and operator from the foundation. Compliance with the allowable stresses and design factors set forth in this specification does not guarantee that the crane will not be dismounted from its foundation in the event of a gross overload such as might occur in the event of snagging the supply boat.

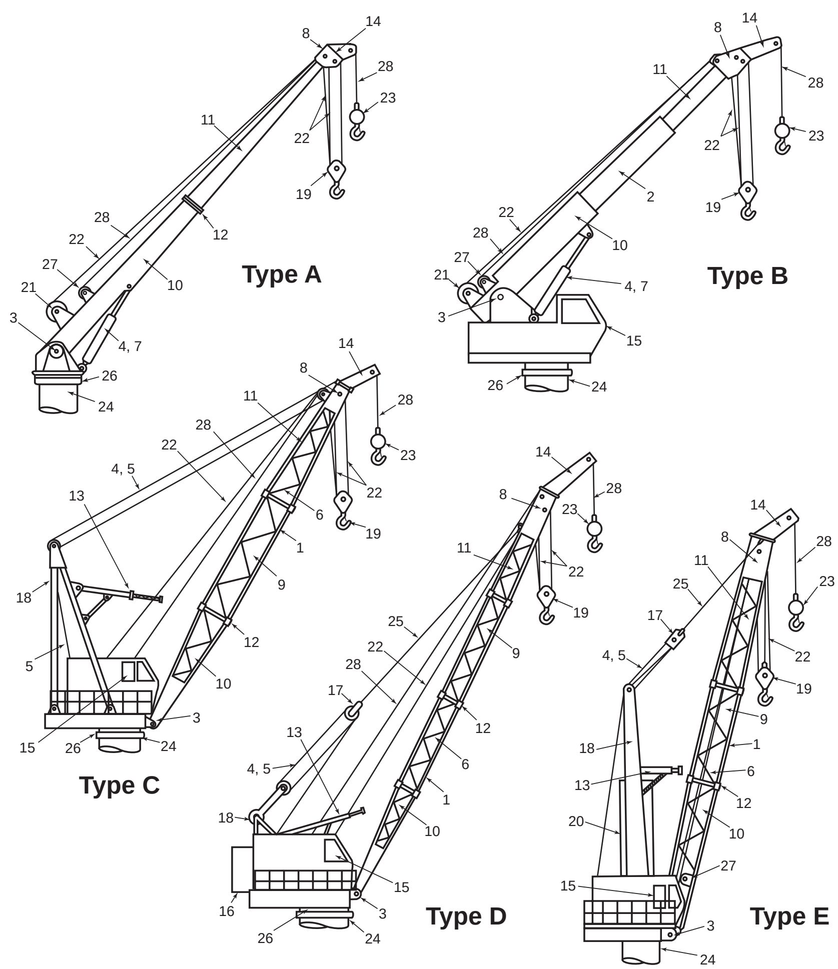


Figure 1—Crane Assembly Types

No.*	Component	Type, See Figure 1				
		A	B	C	D	E
1	Boom Chord	—	—	X	X	X
2	Boom Extension	—	X	—	—	—
3	Boom Foot Pin	X	X	X	X	X
4	Boom Hoist Mechanism	X	X	X	X	X
5	Boom Hoist Wire Rope or Boom Line	—	—	X	X	X
6	Boom Lacing	—	—	X	X	X
7	Boom Lift Cylinder	X	X	—	—	—
8	Boom Point Sheave Assembly or Boom Head	X	X	X	X	X
9	Boom Section, Insert	—	—	X	X	X
10	Boom Section, Lower, Base or Butt	X	X	X	X	X
11	Boom Section, Upper, Point or Tip	X	X	X	X	X
12	Boom Splice	X	—	X	X	X
13	Boom Stop	—	—	X	X	X
14	Boom Tip Extension or Jib	X	X	X	X	X
15	Cab	—	X	X	X	X
16	Counterweight	—	—	—	X	—
17	Floating Harness or Bridle	—	—	—	X	X
18	Gantry, Mast or A-frame	—	—	X	X	X
19	Hook Block	X	X	X	X	X
20	King Post or Center Post	—	—	—	—	X
21	Main Hoist Drum	X	X	—	—	—
22	Main Hoist Rope or Load Line	X	X	X	X	X
23	Overhaul Ball	X	X	X	X	X
24	Pedestal or Base	X	X	X	X	X
25	Pendant Line	—	—	—	X	X
26	Swing-circle Assembly	X	X	X	X	—
27	Whip Line or Auxiliary Hoist Drum	X	X	—	—	X
28	Whip Line or Auxiliary Hoist Rope	X	X	X	X	X

Note: * See Figure 1.

Figure 2—Crane Nomenclature

1.3 CRITICAL COMPONENTS

A critical component is any component of the crane assembly devoid of redundancy and/or auxiliary restraining devices whose failure would result in an uncontrolled descent of the load or uncontrolled rotation of the upper-structure. Due to their criticality, these components are required to have stringent design, material, traceability, and inspection requirements. The manufacturer shall prepare a list of all critical components for each crane. Appendix A contains an example list of critical components.

1.4 COMMENTARY

Further information and references on various topics contained in this specification are included in the Commentary found in Appendix B. The section numbers in Appendix B correspond to the section numbers of this specification. For example, Section 4.3 of this specification, entitled *In-service Loads*, corresponds to Section B.4.3 in Appendix B.

1.5 RECORD RETENTION

The manufacturer shall maintain all inspection and testing records for 20 years. These records shall be employed in a quality audit program of assessing malfunctions and failures for the purpose of correcting or eliminating design, manufacturing, or inspection functions, which may have contributed to the malfunction or failure.

1.6 MANUFACTURER SUPPLIED DOCUMENTATION

The manufacturer shall supply to the purchaser certain documentation for each crane manufactured. Unless otherwise agreed to by the purchaser, the documentation shall include:

1. Load and information charts per Section 4.2.
2. Crane foundation design forces and moments per Section 5.2.

3. List of all critical components per Section 1.3 and certification that these components meet the API Spec 2C material, traceability, welding (as applicable), and nondestructive examination requirements.

4. *Operations, Parts, and Maintenance Manual*.

5. If requested by the purchaser, failure mode assessments for gross un-intended overloads as per Section 4.6.

2 References

2.1 STANDARDS

The following standards contain provisions, which through reference herein, constitute provisions of this standard. Unless a specific edition is referenced in this section, the latest edition of the referenced standard may be used.

API

RP 2A	*Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design*
RP 2D	*Recommended Practice for Operation and Maintenance of Offshore Cranes*
Spec 2H	*Specification for Carbon Manganese Steel Plate for Offshore Platform Tubular Joints*
RP 2N	*Recommended Practice for Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions*
RP 2X	*Recommended Practice for Ultrasonic Examination of Offshore Structural Fabrication and Guidelines for Qualifications of Technicians*
Spec 9A	*Specification for Wire Rope*
RP 14C	*Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms*
RP 14F	*Recommended Design and Installation for Unclassified and Class I, Division 1 and Division 2 Locations*
RP 500	*Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2*
RP 505	*Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1 and Zone 2*

ABMA[1]

Std 9	*Load Ratings and Fatigue Life for Ball Bearings*
Std 11	*Load Ratings and Fatigue Life for Roller Bearings*

[1]American Bearing Manufacturers Association, 2025 M Street, NW, Suite 800, Washington D.C. 20036. www.abma-dc.org

AGMA[2]

ANSI 6010-F97	*Standard for Spur, Helical, Herringbone and Bevel Enclosed Drives*
ANSI 2001-C95	*Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth*
908-B89	*Information Sheet—Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical, and Herringbone Gear Teeth*

AISC[3]

Manual of Steel Construction—Allowable Stress Design, 9th Edition

ANSI[4]

A14.3	*Safety Requirements for Fixed Ladders*
A1264.1	*Safety Requirements for Workplace Floor and Wall Openings, Stairs, and Railing Systems*
B18.2.1	*Square and Hex Bolts and Screws (Inch Series)*

ASME[5]

Boiler and Pressure Vessel Code, Section IX—Welding and Brazing Qualifications

ASNT[6]

SNT-TC-1A	*Recommended Practice SNT-TC-1A*

ASTM[7]

A 295	*Standard Specification for High-Carbon Anti-Friction Bearing Steel*
A 320/A 320M	*Standard Specification for Alloy/Steel Bolting Materials for Low-Temperature Service*
A 578/A 578M	*Standard Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications*
A 770/A 770M	*Standard Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications*
E 23	*Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

[2]American Gear Manufacturers Association, 500 Montgomery Street, Suite 350, Alexandria, Virginia 22314. www.agma.org
[3]American Institute of Steel Construction, Inc., One East Wacker Drive, Suite 3100, Chicago Illinois 60601. www.aisc.org
[4]American National Standards Institute, 25 West 43rd Street, 4 Floor, New York, New York 10036. www.ansi.org
[5]ASME International, 3 Park Avenue, New York, New York 10016-5990. www.asme.org
[6]American Society for Nondestructive Testing, Inc., 1711 Arlington Lane, P.O. Box 28518, Columbus, Ohio 43228-0518. www.asnt.org
[7]ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959. www.astm.org

E 45 *Standard Method for Determining the Inclusion Content of Steel*

AWS[8]

D1.1 *Structural Welding Code—Steel*

D14.3/D 14.3M *Specification for Welding Earthmoving and Construction Equipment*

ISO[9]

281 *Roller bearings—Dynamic load ratings and rating life*

TS 13725 *Hydraulic fluid power—Cylinders—Method for determining the buckling load*

SAE[10]

J115 *Safety Signs for Construction Equipment*

J429G *Mechanical and Material Requirements for Externally Threaded Fasteners*

J919 *Sound Measurement—Off-Road Work Machines—Operator—Singular Type*

United States Government

CFR *Code of Federal Regulations*

2.2 OTHER REFERENCES

The following standards and specifications contain useful information.

ANSI/NFPA[11]

National Electric Code

ASME[5]

HST-4 *Performance Standard for Overhead Electric Wire Rope Hoists*

ASME Boiler and Pressure Vessel Code, Section V—Nondestructive Examination

ASTM[7]

E 709 *Standard Guide for Magnetic Particle Examination*

SI 10 *American National Standard for Use of the International System of Units (SI): The Modern Metric System*

IEEE[12]

Std 45 *Recommended Practice for Electrical Installation on Shipboard*

ANSI Std 268 *American National Standard for Metric Practice*

SAE[10]

J48 *Guidelines for Fluid Level Indicators*

J223 *Symbols and Color Codes for Maintenance Instructions, Container, and Filler Identification*

J987 *Rope Supported Lattice-Type Boom Crane Structures—Method of Test*

J1063 *Cantilevered Boom Crane Structure—Method of Test*

J1238 *Rating Lift Cranes on Fixed Platforms Operating in the Ocean Environment*

3 Definitions, Abbreviations, and Units

3.1 DEFINITIONS

3.1.1 A-frame: See **gantry**, also known as **mast** (see Figure 1, item 18).

3.1.2 allowable rope load: The "nominal" breaking strength of the rope divided by a design factor.

3.1.3 auxiliary hoist: See **whip line** (see Figure 1, item 27).

3.1.4 axis of rotation: The vertical axis around which the crane upper-structure rotates.

3.1.5 base (mounting): See **pedesta**l (see Figure 1, item 24).

3.1.6 bearing raceway: The surface of the bearing rings which contact the rolling element (balls or rollers) of the swing-bearing assembly.

3.1.7 bearing ring: The rotating and stationary rings that house the rolling elements (balls or rollers) of the swing-bearing assembly.

3.1.8 boom: A member hinged to the revolving upper-structure and used for supporting the hoist tackle.

3.1.9 boom angle: The angle above or below horizontal of the longitudinal axis of the base boom section.

3.1.10 boom angle indicator: An accessory which measures the angle of the boom above horizontal.

3.1.11 boom chord: A main corner member of a lattice type boom (see Figure 1, item 1).

3.1.12 boom extension: Intermediate section of a telescoping boom (see Figure 1, item 2).

3.1.13 boom foot-pin: The boom pivot point on the upper-structure (see Figure 1, item 3).

[8]American Welding Society, 550 NW LeJeune Road, Miami, Florida 33135. www.aws.org
[9]International Organization for Standardization, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. www.iso.org
[10]Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096-0001. www.sae.org
[11]National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169. www.nfpa.org
[12]Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, New Jersey 08854-1331. www.ieee.org

3.1.14 boom hoist: See Section 8.2 and its sub-sections. The hoist mechanism responsible for raising and lowering the boom.

3.1.15 boom hoist mechanism: Means for supporting the boom and controlling the boom angle (see Figure 1, item 4).

3.1.16 boom hoist wire rope: Wire rope that operates on a drum controlling the angle positioning of the boom (see Figure 1, item 5).

3.1.17 boom lacing: Structural truss members at angles to and supporting the boom chords of a lattice type boom (see Figure 1, item 6).

3.1.18 boom length: The straight-line distance from the centerline of boom foot-pin to the centerline of the boom-point load hoist sheave pin, measured along the longitudinal axis of the boom.

3.1.19 boom lift-cylinder: Means for supporting the boom and controlling the boom angle (see Figure 1, item 7).

3.1.20 boom line: Boom hoist rope that reels on drums or passes over sheaves. See **boom hoist wire rope**.

3.1.21 boom-point sheave assembly: An assembly of sheaves and a pin built as an integral part of the boom-point (see Figure 1, item 8).

3.1.22 boom splices: Splicing connections for sections of basic crane boom and additional sections usually of the splice plate type, pin type, or butt type (see Figure 1, item 12).

3.1.23 boom stop: A device used to limit the angle of the boom at the highest recommended position (see Figure 1, item 13).

3.1.24 boom-tip extension: See **jib** (see Figure 1, item 14).

3.1.25 brake: A device used for retarding or stopping motion or holding.

3.1.26 bridle: See **floating harness** (see Figure 1, item 17).

3.1.27 cab: An enclosure for the operator and the machine operation controls (see Figure 1, item 15).

3.1.28 clutch: A means for engagement or disengagement of power.

3.1.29 counterweight: Weight used to supplement the weight of the machine in providing stability for lifting working loads and usually attached to the rear of the revolving upper-structure (see Figure 1, item 16).

3.1.30 critical component: Any component of the crane assembly devoid of redundancy and/or auxiliary restraining devices whose failure would result in an uncontrolled descent of the load or uncontrolled rotation of the upper-structure. See examples in Appendix A of this specification.

3.1.31 C_V: Vertical design coefficient that is multiplied by the Safe Working Load (SWL) to provide the vertical design load.

3.1.32 designated: Selected or assigned by the employer or the employer's representative as being qualified to perform specific duties.

3.1.33 design load: The vertical design load is equal to the SWL times the vertical design coefficient C_V. Other loads considered in design of the crane include offload, sideload, environmental loads, loads due to crane base motion, and other loads as defined herein.

3.1.34 design requirements: The requirements set forth by the manufacturer's engineering authority for materials, manufacturing, fabrication, and inspection procedures to be employed in the production of the crane.

3.1.35 dynamic loading: Loads introduced into the machine or its components due to accelerating or decelerating loads.

3.1.36 enclosure: A structure that may provide environmental protection for the machine.

3.1.37 fitness-for-purpose: The manufacture or fabrication of an assembly or component to the quality level required (but not necessarily the highest level attainable) to assure material properties, environmental interactions, and any imperfections present in the assembly or connection are compatible with the intended purpose. Fitness-for-purpose connotes an assembly or component may contain material or fabrication imperfections of sizeable dimensions but their presence has no influence on its performance or reliability.

3.1.38 fixed platform: A bottom supported, stationary structure without significant movement in response to waves and currents in operating conditions. Examples are fixed platforms with jacket and pile supports, jack-up rigs, and submersible bottom-supported rigs.

3.1.39 floating harness (also known as bridle): A frame equipped with sheaves and connected to the boom by stationary ropes usually called pendants (see Figure 1, item 17).

3.1.40 floating platform/vessel: A moving structure that the crane is mounted on. Examples are TLPs, spars, semisubmersibles, drillships, and FPSOs.

3.1.41 foundation bolts or fasteners: The bolts used to connect a swing bearing to the upper-structure and/or pedestal.

3.1.42 fracture control plan: The consideration of material properties, environmental exposure conditions, potential material and fabrication imperfections, and methods of inspection for the purpose of eliminating conditions which could result in failure under the design requirements for the projected life of the crane.

3.1.43 gantry (also known as A-frame or mast): A structural frame, extending above the upper-structure to which the boom support ropes are reeved (see Figure 1, item 18).

3.1.44 guy rope: A non-operating, standing wire rope that maintains a constant distance between the points of attachment to the components connected by the wire rope.

3.1.45 hoisting: The process of lifting.

3.1.46 hoist mechanism: A hoist drum and rope reeving system used for lifting and lowering loads.

3.1.47 hoist rope: Wire rope involved in the process of lifting.

3.1.48 hoist tackle: Assembly of ropes and sheaves arranged for pulling.

3.1.49 hook block: Block with a hook attached used in lifting service. It may have a single sheave for double or triple line or multiple sheaves for four or more parts of line (see Figure 1, item 19).

3.1.50 hook rollers: Rollers that prevent the lifting of the revolving upper-structure from the roller path. Hook rollers are a means to connect the upper-structure to the foundation or pedestal.

3.1.51 H_{sig}**:** The sea significant wave height existing that is associated with the load chart, rating, or other condition herein.

3.1.52 in service: A crane is in service when the operator is in control of the crane.

3.1.53 jib (also known as tip extension): An extension attached to the boom point to provide added boom length for lifting specified loads (see Figure 1, item 14).

3.1.54 king-pin: Vertical pin or shaft that acts as a rotation-centering device and connects the revolving upper-structure and base mounting.

3.1.55 king post: A tubular member that acts as the centerline of rotation and as the connective member to the platform (see Figure 1, item 20).

3.1.56 lacing: See **boom lacing** (see Figure 1, item 6).

3.1.57 lattice boom: Boom of open construction with lacing between main corner members (chords) in form of a truss.

3.1.58 load block-lower: The assembly of hook or shackle, swivel, sheaves, pins, and frame suspended by the hoisting ropes.

3.1.59 load block-upper: The assembly of shackle, swivel, sheaves, pins, and frame suspended from the boom point.

3.1.60 load line (also known as hoist line): In lifting crane service it refers to the main hoist rope (see Figure 1, item 22). The secondary hoist rope is referred to as a **whip line** or **auxiliary line** (see Figure 1, item 28).

3.1.61 load ratings: Crane ratings in pounds (kilograms) established by the manufacturer in accordance with Section 4.

3.1.62 loose gear: Includes all slings, nets, hooks, baskets, shackles, chains, ropes, cables, life vests, etc., necessary in crane operations to attach the load to the crane hook or block and to move the load. (Life jackets and life vests are terms for a Coast Guard approved life saving device able to support an unconscious person in the face-up position. Work vests are buoyant flotation devices, usually made of plastic and foam. Work vests are not approved for work over water or for personnel transfer.)

3.1.63 luffing: The operation of changing boom angle in a vertical plane.

3.1.64 main hoist line: See **loadline** (see Figure 1, item 22).

3.1.65 major structural revision: A change to the structure that reduces the load-carrying capability of any structural component or for which a revised load chart has been established.

3.1.66 mast (also known as gantry): A frame hinged at or near the boom hinge for use in connection with supporting a boom. The head of the mast is usually supported and raised or lowered by the boom hoist ropes.

3.1.67 offboard lift: A crane lifting a load from or to anywhere not on the platform/vessel that the crane is mounted on (from/to supply boats, for example).

3.1.68 onboard lift: A crane lifting a load from and to the deck of the platform/vessel that the crane is mounted on.

3.1.69 operator's station: The designated location for the operator to operate the machine.

3.1.70 out-of-service: A crane is out-of-service when the operator is not controlling the crane. Out-of-service conditions may be with the boom out of the boom rest or in the boom rest (stowed).

3.1.71 overhaul: Ability of a weight on the end of the hoist line to unwind rope from the drum when the brake is released.

3.1.72 overhaul ball: The weight on a single part line used to pull the wire rope off the drum with gravitational assistance (see Figure 1, item 23).

3.1.73 pawl (dog): A device for positively holding a member against motion in one or more directions.

3.1.74 pedestal (also known as base): The supporting substructure upon which the revolving upper-structure is mounted (see Figure 1, item 24).

3.1.75 pendant line (also known as guy rope): A non-operating standing rope of specified length with fixed end connections (see Figure 1, item 25).

3.1.76 pitch diameter: Root diameter of drum, lagging or sheave, plus the diameter of the rope (see Figures 5 and 6).

3.1.77 power controlled lowering: A system or device in the power train, other than the load hoist brake, that can control the lowering speed of the load hoist mechanism.

3.1.78 prototype: An initial manufactured component or unit of a specific design adhering to this edition of API Spec 2C.

3.1.79 qualified: A person who, by possession of a recognized degree, certificate of professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work.

3.1.80 rated capacity: The rated load or SWL at specified radii as established by the manufacturer which are the maximum loads at those radii covered by the manufacturer's warranty for the conditions specified.

3.1.81 reeving: A rope system where the rope travels around drums and sheaves.

3.1.82 revolving upper-structure: The rotating upper frame structure and the operating machinery mounted thereon (also known as turntable).

3.1.83 ring gear: See **swing gear** (also known as bull gear).

3.1.84 roller path: The surface upon which the rollers that support the revolving upper-structure bear. It may accommodate cone rollers, cylindrical rollers, or live rollers.

3.1.85 rolling element: The balls or rollers contained between the rings of the swing-circle bearing.

3.1.86 rotating base: See **revolving upper-structure**.

3.1.87 rope: Refers to wire rope unless otherwise specified.

3.1.88 rotation-resistant rope: A wire rope consisting of an inner layer of strand laid in one direction covered by a layer of strand laid in the opposite direction. This has the effect of counteracting torque by reducing the tendency of the finished rope to rotate.

3.1.89 running rope: A rope which travels around sheaves or drums.

3.1.90 Safe Working Load (SWL) (see rated capacity): The maximum rated load within crane rated capacity for the given operating conditions.

3.1.91 shall: This word indicates that the rule is mandatory and must be followed.

3.1.92 should: This word indicates that the rule is a recommendation, the advisability of which depends on the facts in each situation.

3.1.93 sideload: A load applied at an angle to the vertical plane of the boom.

3.1.94 sling: An assembly that connects the load to the material handling equipment.

3.1.95 standing (guy) wire rope: A supporting, non-operating wire rope that maintains a constant distance between the points of attachment to the two components connected by the wire rope.

3.1.96 structural competence: The ability of the machine and its components to withstand the stresses imposed by applied loads.

3.1.97 swing (slewing): Rotation of the upper-structure for movement of loads in a horizontal direction about the axis of rotation.

3.1.98 swing bearing: A combination of rings with balls or rollers capable of sustaining radial, axial, and moment loads of the revolving upper-structure with boom and load.

3.1.99 swing circle: See **swing bearing** and **roller path**.

3.1.100 swing-circle assembly: (See Figure 1, item 26.) The swing-circle assembly is the connecting component between the crane revolving upperstructure and the pedestal for cranes of types A, B, C, and D. It allows crane rotation and sustains the moment, axial, and radial loads imposed by crane operation.

3.1.101 swing gear (also known as ring gear or bull gear): External or internal gear with which the swing pinion on the revolving upper-structure meshes to provide swing motion.

3.1.102 swing mechanism: The machinery involved in providing dual directional rotation of the revolving upper-structure.

3.1.103 swivel: A load-carrying member with thrust bearings that permit rotation under load in a plane perpendicular to the direction of the load.

3.1.104 swiveling: The rotation of the load attachment portion (hook or shackle) of a load block (lower) or hook assembly about its axis of suspension in relation to the load line(s).

3.1.105 tail swing (rear end radius): Clearance distance from the center of rotation to the maximum rear extension of the revolving upper-structure.

3.1.106 telescoping boom: Consists of a base boom from which one or more boom sections are telescoped for additional length (see Figure 1, Type B, items 2, 10, 11).

3.1.107 torque converter: Auxiliary transmission connected to the prime mover that multiplies engine torque as load increases with a corresponding decrease in speed.

3.1.108 two-blocking: The condition when the lower load block or hook assembly contacts the upper load block or boom-point sheave assembly.

3.1.109 upper-structure: See **revolving upper-structure**.

3.1.110 whipline: A secondary rope system, usually of lighter load capacity than provided by the main rope system. Also known as **auxiliary** (see Figure 1, items 27 and 28).

3.1.111 wire rope: A flexible, multi-wired member usually consisting of a core member around which a number of multi-wired strands are "laid" or helically wound.

3.1.112 working load: The external load in pounds (kilograms), applied to the crane including the weight of load-attaching equipment such as load block, shackles, and slings. The maximum allowable working load for a given condition would be the SWL.

3.2 ABBREVIATIONS

The following abbreviations are used in this publication:

ABMA	American Bearing Manufacturers Association
AGMA	American Gear Manufacturers Association
AISC	American Institute for Steel Construction
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society of Nondestructive Testing
ASTM	American Society of Testing and Materials
AWS	American Welding Society
ISO	International Standards Organization
SAE	Society of Automotive Engineers

3.3 UNITS

Many of the formulae in this publication are dependent on the input quantities having the proper units to compute the correct result. The formulae given in this publication are given in the U.S. Customary System (English system) of units. Primary units used are ft (length), lb. (force), sec. (time), and degrees (angles). These results may be converted to International System of Units (SI) metric equivalents, if desired. Since some of the formulae are "units dependent," the U.S. units should be input in the formulae and U.S. unit results obtained, then the results may be converted to SI units. Conversion factors from U.S. to SI units are given below. For additional conversions, refer to ASTM SI 10 or ANSI/IEEE Std 268.

1 meter = 3.2808 ft
1 kilogram = 2.2046 lb. force
1 Newton = 0.2248 lb. force
1 Joule = 0.737557 ft-lb. force
°Celsius = $^5/_9 \times$ (°Fahrenheit – 32)

4 Crane Ratings

4.1 GENERAL

Ratings shall be established for onboard lifts (crane lifts to and from the deck of the platform/vessel that the crane is mounted on) and for offboard lifts (crane lifts from/to supply vessels, etc.). Offshore cranes are subjected to a variety of loadings due to the environment they operate in including vertical loads, offload, sideload, wind loads and others. This is true of fixed platform cranes for offboard lifts, but even more so for onboard and offboard lifts for cranes on floating platforms/vessels. The guidelines herein for rating cranes cannot cover all conditions and crane installations, particularly for cranes mounted on floating platforms and vessels. The purchaser and the supplier therefore must take care to determine the conditions that apply to the specific application and determine safe crane rated loads and operating limits accordingly.

For cranes on floating platforms/vessels, it is strongly recommended that crane rated loads be developed that consider the motions of that particular vessel and the crane's location on the vessel. This Vessel Specific Method of establishing crane ratings is preferred because it should provide the best evaluation of the floating platform/vessel effects on rated load for a given operating condition. The Vessel Specific Method requires the platform/vessel owner to provide sufficient information to determine crane motions and accelerations for the specific operating conditions desired. The required information is discussed in the Commentary. In the absence of this information, the General Method design motions and accelerations are provided in the following sections that were developed to be representative for various types of floating platforms/vessels. The Default Dynamic Method is not recommended for floating platform/vessels and should only be used to establish ratings for fixed platform cranes in calm conditions in which the movement of the supply boat relative to the platform is restrained by tethering or other means.

Table 1 summarizes some of the key design parameters discussed in the following sections, where to obtain the

Table 1—Summary of Design Parameters

Design Parameter	Design Condition			
	In-service Offboard Lift	In-service Onboard Lift	Out-of-service (Boom Not Stowed)	Out-of-service (Stowed)
Supply Boat Deck Velocity V_d	Purchaser Specified or Table 2	n/a	n/a	n/a
Crane Boom Tip Velocity V_c	Purchaser Specified or Table 2	n/a	n/a	n/a
Hoist Velocity V_h Used for Load Calculations	Max Available—Must Exceed or Equal Eq. 4.2 Value	n/a	n/a	n/a
Vertical Design Load	Eq. 4.1 $C_v \times$ SWL	Purchaser Specified or Table 3 $C_v \times$ SWL	n/a	n/a
Minimum Required Hoist Velocity for Lifting Conditions (V_{hmin})	Eq. 4.2 Value	n/a	n/a	n/a
Supply Boat Offload Force W_{offSB}	Eq. 4.3 or Eq. 4.3 Alt	n/a	n/a	n/a
Supply Boat Sideload Force W_{sideSB}	Eq. 4.4 or Eq. 4.4 Alt	n/a	n/a	n/a
Crane Inclination Sideload	Purchaser Specified or Table 4/Eq. 4.5 Value	Purchaser Specified or Table 4/Eq. 4.5 Value	Purchaser Specified or Table 4/Eq. 4.5 for Non-stowed Conditions	Purchaser Specified or Table 4/Eq. 4.5 for Extreme Vessel Case
Crane Base Horizontal Acceleration Loads Acting on Vertical Design Load	Purchaser Specified or Table 4/Eq. 4.6 – 4.8 Value	Purchaser Specified or Table 4/Eq. 4.6 – 4.8 Value	n/a	n/a
Crane Base Horizontal Acceleration Loads Acting on Boom and Other Crane Parts	Purchaser Specified or Table 4 and 5 Accelerations	Purchaser Specified or Table 4 and 5 Accelerations	Purchaser Specified or Table 4 and 5 Accelerations for Non-stowed Conditions	Purchaser Specified or Table 4 and 5 Accelerations for Extreme Vessel Case
Environmental Loads Due to Wind and Ice or Snow	Per Section 4.5	Per Section 4.5	Per Section 4.5 for Non-stowed Conditions	Per Section 4.5 for Extreme Vessel Case

Note: n/a—not applicable

parameter, and whether it is applicable for out-of-service and in-service offboard and onboard conditions.

4.1.1 Crane Rated Loads

It is the intent of this specification that all load rating charts present to the operator the SWLs that can actually be lifted and swung (slewed) on the specific installation, and under the specific conditions for which the charts are applicable. Therefore, the SWL shown on these charts shall be the *least* of the following:

a. Maximum load based on all structural components (except king post and pedestal) that does not cause the allowable stresses of Section 5 to be exceeded on any component when the crane is simultaneously subjected to SWL × C_v vertical design load plus all loads due to supply boat motion, platform/vessel motion, platform/vessel static inclination, and environmental loads as defined in Sections 4.3 and 4.5.

b. Maximum load based on king post or pedestal that does not cause the allowable stresses of Section 5 to be exceeded with the same loads as item (a) above but with the added load factor given in Section 5.2.

c. Maximum load based on loadline reeving and wire rope design factors in accordance with Section 7.2.

d. Maximum load based on load hoist line pull available, considering line reeving losses with manufacturer's design reeving, for a load at the boom tip, calculated in accordance with Section 8.1.7.

e. Maximum load based on boomline reeving and wire rope design factors in accordance with Section 7.2.

f. Maximum load based on boom pendant wire rope in accordance with Section 7.2.

g. Seventy-five percent of maximum load based on boom hoist line pull available, considering line reeving losses with manufacturer's design reeving for boom line, calculated in accordance with Section 8.1.7.

h. Maximum load based on Swing-circle Assembly capability, where applicable, as defined in Section 9.2.1.

i. Maximum load based on swing-mechanism capability as defined in Sections 9.1.1 and 9.1.2.

The published "load chart" rated load shall be reduced from the above calculated rated loads by the weight of the hook and block excluding the load hoist rope.

4.1.2 Personnel Rated Loads

The rated load when handling personnel shall be the least of:

a. Thirty-three percent of the calculated SWL for non-personnel load ratings.
b. Max load based on load line reeving and wire rope design factors per Section 7.2.4.3.
c. Max load based on load hoist line pull available considering line reeving losses with manufacturer's design reeving for a load at the boom tip, calculated in accordance with Section 8.1.7.

The published "load chart" rated load shall be reduced from the above calculated rated loads by the weight of the hook and block excluding the load hoist rope. The personnel net shall be considered part of the load.

4.1.3 Crane Out-of-service Conditions

Section 4.4 defines loads the crane is typically subjected to when it is out-of-service. The crane must also be designed to accept these loads without exceeding the allowable stress levels and safety factors defined in the other sections of this specification.

4.2 LOAD RATING AND INFORMATION CHARTS

4.2.1 Load Rating Chart(s)

A substantial and durable load chart(s) with clearly legible letters and figures shall be provided with each crane and be securely fixed to the crane in a location easily visible to the operator. The chart(s) shall provide the following information:

a. The manufacturer's approved load ratings, at operating radii not exceeding either 5 ft or 2 m increments, and corresponding boom angles down to horizontal for the specified boom length and jib length where applicable.
b. The basis of ratings shall be plainly stated and shall be in compliance with all applicable sections of this specification. This shall include definition of conditions for which the chart is applicable such as onboard or offboard lifts, waveheight, etc. The chart shall state which of the three methods were used to determine the ratings (Vessel Specific, General, or Default Dynamic methods) as defined in Section 4.3.
c. Reeving diagrams or charts (shown either on the load chart or by chart reference to the specific crane's operating manual) recommending the number of parts of line for each rope used on the crane.
d. API minimum recommended hook speed at the supply boat elevation per Section 4.3.1 (see Eq. 4.2).
e. The name of the platform or vessel that the crane rating chart applies to.
f. Crane manufacturer and crane serial number.
g. There shall be load charts defining SWL for specific lift conditions. The load chart shall be in table form listing rated load versus all working radii. The crane shall not be operated outside of the specified lift conditions. More than one load chart may be developed to define crane SWL for different environmental conditions. Figure 3 shows an example plot of SWL versus lift radius for various conditions for a crane.
h. The personnel rating of the crane shall be supplied on the load chart for all working radii. If the crane is not personnel rated that shall be indicated on the chart.

The crane Load Rating Chart must be reviewed and revised if any of the following occurs:

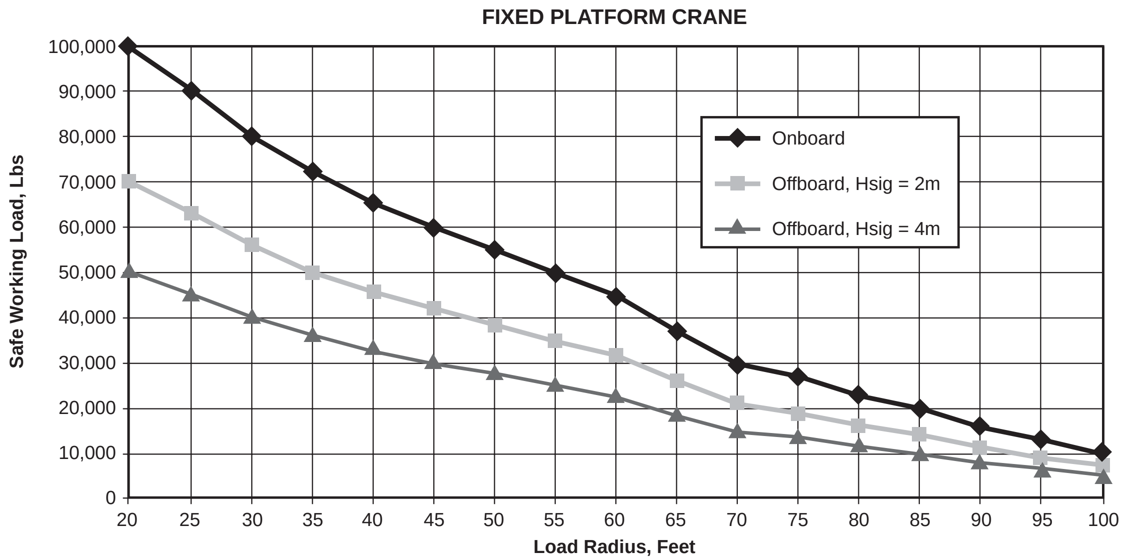
a. The crane is moved to another location. This includes relocation on the existing platform or moving to another platform or vessel.
b. The boom or jib length is changed.
c. Any of the wire rope components are replaced with a wire rope with a lower breaking strength or if the load block or overhaul ball are exchanged for heavier components.
d. The number of "Parts of Line" change for any of the wire rope components or the Boom, Hoist, or Auxiliary Reeving Systems are altered.
e. Any of the critical components listed in Appendix A are altered in any way that reduces their strength or functionality.
f. The electrical, hydraulic, or power plant components of the Prime Mover System are altered in any way that reduces available line speed or line pull.
g. The crane is derated.

Where re-rating of a crane is necessary, follow API RP 2D recommendations and requirements.

4.2.2 Information Chart

In addition to the load chart, an information chart with clearly legible letters and figures shall be provided with each crane and be securely fixed to the crane in a location easily visible to the operator. The information chart shall provide information, which are common to the use of all of the charts referenced in Section 4.2.1 including, but not limited to, the following:

a. Precautionary or warning notes relative to limitations on equipment and operating procedures shall be provided.
b. Description of the Main Hoist Cable, including length, type of construction, and breaking strength.
c. Description of the Auxiliary (Whip) Hoist Cable, where applicable, including length, type of construction, and breaking strength.
d. Description of the Boom (Luffing) Hoist Cable, where applicable, including length, type of construction, number of parts of line, and breaking strength.



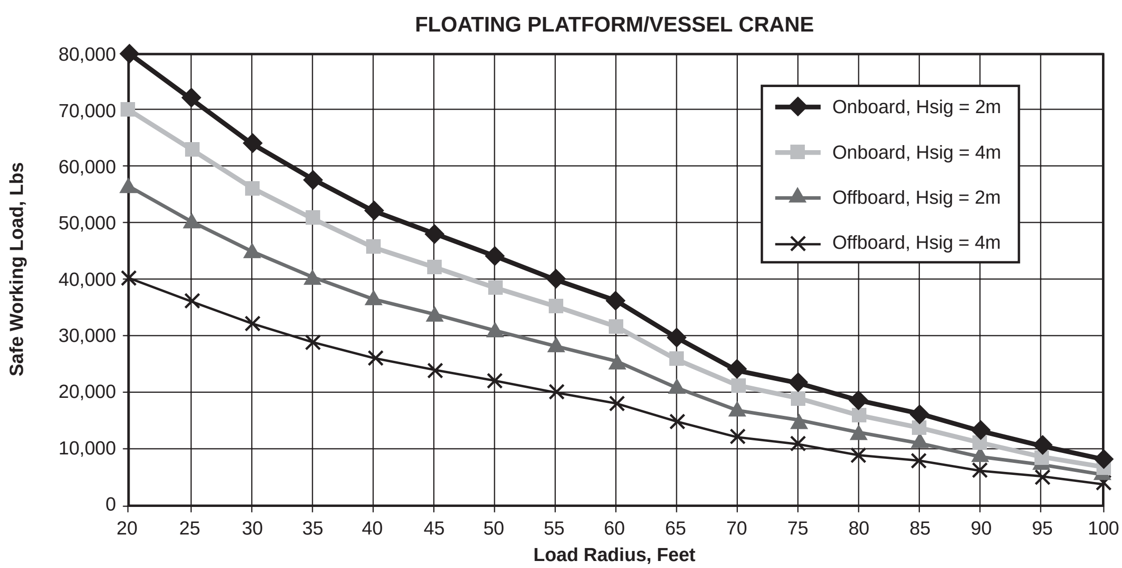


Figure 3—Plots of Rated Loads for Various Operating Conditions

e. Description of the Boom Pendant lines, where applicable, including length, type of construction, number of parts of line, and breaking strength.

f. Maximum Hook Travel for the main hook for all rigging configurations (parts of line).

g. Maximum Hook Travel for the Auxiliary (Whip) hook as rigged.

h. Maximum and Minimum Hook Radii for the main hook with limits set as recommended.

i. Maximum and Minimum Hook Radii for the Auxiliary (Whip) hook with limits set as recommended.

j. Maximum Available Hook Speed for the main hook, with the hook positioned at the supply boat elevation and the platform/vessel at operational conditions for all rigging configurations (parts of line).

k. Maximum Available Hook Speed for the Auxiliary (Whip) hook, where applicable, with the hook positioned at the supply boat elevation and the platform/vessel at operational conditions.

l. Notes or instructions regarding the use of any Emergency Load Release Devices, where applicable.

m. Notes or instructions regarding the operation of any Automatic Overload Protection Devices, where applicable.

4.3 IN-SERVICE LOADS

During use, the crane is subjected to loads due to its own weight, the lifted load, environment, motions of the platform/vessel, and dynamics caused by movements such as hoisting, boom luffing, slewing, and for offboard lifts, motions of the supply vessel the load is being lifted from.

The crane vertical design load is to be equal to the rated load or SWL multiplied by the dynamic coefficient C_v determined in Section 4.3.1. Offlead and sidelead loads, loads due to supply boat motions, and the static inclination and motions of the crane base on floating installations shall be taken into consideration as defined in Section 4.3.2. Wind, ice, and other environmental loads acting on the crane shall be taken into consideration as defined in Section 4.5. For the specified lift conditions, the maximum SWL shall be the largest lifted load that satisfies the requirements of Section 4.1.1 when the worst combination of all of the loads defined herein are applied to the crane.

Three methods are given for calculating the dynamic forces acting on a crane in a specified seastate. These methods and their limitations are discussed in the following paragraphs. The methods are:

1. Vessel Specific Method,
2. General Method, and
3. Default Dynamic Method.

Floating platform/vessel crane ratings shall be determined by either the Vessel Specific Method or General Method. Fixed platform crane ratings shall be determined by either the General Method or with special restrictions, the Default Dynamic Method.

Vessel Specific Method. The Vessel Specific Method is the preferred method for floating platform/vessel crane installations. For the Vessel Specific Method, the purchaser shall supply the velocity V_c used in Eq. 4.1 to calculate the dynamic coefficient C_v. The V_c shall be the boom tip velocity for a given operating condition and may be calculated by investigating the motion behavior of the crane and the vessel it is mounted on. The accuracy of this method depends on how well the motions of the crane boom tip can be calculated. V_d for the supply vessel shall be taken from Table 2 or it may be specified by the purchaser. For the Vessel Specific Method, the purchaser shall specify the onboard lift C_v instead of using Table 3 and the platform/vessel static inclinations and the crane dynamic horizontal accelerations instead of using Table 4. Required information for the Vessel Specific Method is discussed in the commentary.

General Method. For the General Method, the velocity V_d and V_c shall be taken from Table 2 for offboard lifts. These velocities were based on estimates of motions derived for representative platform/vessels of various types. The commentary discusses the basis for the values given in Table 2. For the General Method, the platform/vessel values from Tables 3 and 4 shall also be used.

Default Dynamic Method. For some offboard lifts from fixed platform installations a fixed dynamic coefficient C_v of 2.0 may be used instead of the method described above. This alternate method is only allowed for fixed platforms in areas with very mild sea and wind conditions such as the Gulf of Mexico and shall only be used in situations where the supply vessel position is maintained constant relative to the platform (such as for a platform-tethered supply vessel). In these special conditions, a dynamic coefficient of 2.0 may be used, offlead and wind forces may be taken as zero, and sideload shall be taken as 2 percent of the vertical design load (Sideload Force = $0.02 \times 2.0 \times$ SWL).

4.3.1 Vertical Design Loads

The vertical design load acting on the crane boom tip shall be the rated load (SWL) multiplied by the vertical dynamic coefficient C_v.

4.3.1.a Offboard Lifts—For offboard lifts, the vertical dynamic coefficient C_v shall be determined from the following expression:

$$C_v = 1 + V_r \times \sqrt{\frac{K}{g \times \mathrm{SWL}}} \qquad \text{(Eq. 4.1)}$$

but not less than 1.33 for fixed platform cranes or 1.40 for floating platform/vessel cranes

where

K = vertical spring rate of the crane at the hook, lb/ft,

SWL = Safe Working Load or Rated Load, lb. SWL is an unknown and therefore will require iteration to obtain C_v. A good starting value for SWL iteration is one-half the design load,

g = acceleration due to gravity, 32.2 ft/sec.^{2},

$V_r = V_h + \sqrt{V_d^2 + V_c^2}$ = relative velocity, ft/sec.,

V_h = maximum actual steady hoisting velocity for the SWL to be lifted, ft/sec.,

V_d = vertical velocity of the supply boat deck supporting the load, ft/sec.,

V_c = vertical velocity of the crane boom tip due to crane base motion, ft/sec.

The crane stiffness K shall be calculated taking into account all elements from the hook through the pedestal structure. The commentary discusses calculation of crane stiffness to be used in this formula.

During offboard lifts, the hoisting velocity shall be fast enough to avoid re-contact after the load is lifted. Unless otherwise agreed to by the purchaser, the minimum steady hoisting velocity (V_{hmin}) for any particular hook load to be lifted shall be:

$$V_{h\min} = 0.1 \times (H_{\text{sig}} + 3.3) \text{ ft/sec.} \qquad \text{(Eq. 4.2)}$$

where

H_{sig} = sea significant wave height for the load chart in question (ft).

The V_h used in Eq. 4.1 to calculate C_v must be the actual maximum available hook speed attainable and must be equal to or larger than V_{hmin}.

4.3.1.b Onboard Lifts—For onboard lifts, the velocities V_d and V_c shall be taken as zero. For the Vessel Specific Method, C_v shall equal 1.33 plus the vertical boom tip dynamic acceleration (g's) determined from the vessel motions analysis for the specific operating conditions. For the General Method, the dynamic coefficient C_v shall be taken from Table 3. For the Default Dynamic Method (fixed platforms only), the dynamic coefficient C_v shall equal 1.33 for onboard lifts.

4.3.2 Horizontal Design Loads

Horizontal loadings shall be taken into consideration in establishing the crane ratings. If more specific data is not available from the purchaser, the effect of offlead, sidelead, crane base static inclination and crane base motions shall be calculated in accordance with this section and shall be applied concurrently with vertical design loads in crane rating calculations.

4.3.2.a Offlead and Sidelead Due to Supply Boat Motion (SB Forces)

All offboard lifts shall include the horizontal loads induced by supply boat motion. The radial offlead load W_{offSB} applied at the boom tip due to supply boat motion shall be:

$$W_{\text{offSB}} = \text{SWL} \times C_v \times \frac{2.5 + (0.457 \times H_{\text{sig}})}{0.305 \times (H_w + \text{BL} \times \sin(\phi))} \qquad \text{(Eq. 4.3)}$$

where

H_w = vertical distance from boom heel pin to supply boatdeck, ft,

SWL = Safe Working Load, lb.,

BL = boom length, ft,

ϕ = boom angle to horizontal.

The horizontal sideload applied at the boom tip due to supply boat motion shall be:

$$W_{\text{sideSB}} = W_{\text{offSB}}/2 \text{ lb.} \qquad \text{(Eq. 4.4)}$$

However, W_{sideSB} shall not be less than $0.02 \times \text{SWL} \times C_v$.

When the purchaser supplies specific offlead and sidelead angles, the offlead and sidelead forces shall be a function of the specified angles as:

$$W_{\text{offSB}} = \text{SWL} \times C_v \times \tan(\text{Offlead Angle}) \text{ lb.} \qquad \text{(Eq. 4.3 alt)}$$

$$W_{\text{sideSB}} = \text{SWL} \times C_v \times \tan(\text{Sidelead Angle}) \text{ lb.} \qquad \text{(Eq. 4.4 alt)}$$

However, W_{sideSB} shall not be less than $0.02 \times \text{SWL} \times C_v$.

4.3.2.b Loads Due to Crane Inclinations (CI Forces) and Crane Motions (CM Forces)

All onboard and offboard lifts shall include the loads induced by crane base static inclination (list or trim) and crane base motions. For the Vessel Specific Method, the boom tip motions resulting from the platform/vessel crane motions shall be determined. The boom tip motions shall be defined for the in-service operating conditions and for the worst non-stowed out-of-service conditions. For the General Method, in absence of any specific data for the vessel, the values in Table 4 may be used. These may not represent the actual conditions for a specific application or platform/vessel. The commentary provides information on the basis of the values given in Table 4.

Platform/vessel static inclinations (list and trim) cause offlead and/or sidelead depending on the crane operating direction relative to the inclination. Static offlead results in a static change in position of the hook compared to level lifting conditions. To account for this, the crane boom angle should be adjusted to bring the hook back to the correct radius and the ratings determined for this configuration. Static sidelead results in a sideload at the boom tip due to the vertical design load equal to:

$$W_{\text{sideCI}} = \text{SWL} \times C_v \times \tan(\text{StaticSideleadAngle}) \text{ lb.} \quad \text{(Eq. 4.5)}$$

The crane static sidelead also causes sideloads to be imparted due to the boom and crane weights. These sideloads shall be calculated in a similar manner and applied to the crane boom and other crane components.

Crane base motions cause offloads and sideloads to be imparted to the boom tip similar to those from supply boat motions. Crane base motions also cause vertical loads, offloads, and sideloads to be imparted due to the boom and crane weights. These loads shall be applied to the crane along the boom and on other affected components. The horizontal accelerations determined for the crane boom tip (purchaser specified for the Vessel Specific Method or from Table 4) shall be applied to the boom and other crane components along with the boom tip horizontal load due to this acceleration times the vertical design load. The horizontal loads from crane base motions (CM forces) acting on the suspended load can be written as:

$$W_{\text{horizontalCM}} = \text{SWL} \times C_v \times \text{Horizontal Acceleration lb.} \quad \text{(Eq. 4.6)}$$

Similar horizontal forces result from the boom and other crane components due to platform/vessel static inclinations and horizontal accelerations. These added horizontal loads shall be calculated for the various crane components and applied to the various crane components. The horizontal loads due to crane motions are applied in the direction of crane base motion. This results in sidelead and offlead forces due to $W_{\text{horizontalCM}}$ of:

$$W_{\text{offCM}} = W_{\text{horizontalCM}} \times \cos(\text{CraneBaseAngle}) \text{ lb.} \quad \text{(Eq. 4.7)}$$

$$W_{\text{sideCM}} = W_{\text{horizontalCM}} \times \sin(\text{CraneBaseAngle}) \text{ lb.} \quad \text{(Eq. 4.8)}$$

where

CraneBaseAngle = angle of crane base motions from direction of boom (0° for only offlead, 90° for only sidelead).

The assumed angle of crane base motions shall be evaluated at several angles including at a minimum 0° and 90° (maximum offlead and sidelead). The lowest SWL resulting from these angle variations shall be selected for a given lifting condition.

4.3.2.c Combination of Horizontal Design Loads

The horizontal loads due to crane motions and due to supply boat motions are combined as follows. The total lifted load induced horizontal dynamic sidelead and offlead forces are:

Sidelead force W_{sidedyn}:

$$W_{\text{sidedyn}} = \sqrt{\{W_{\text{sideSB}}\}^2 + \{W_{\text{sideCM}}\}^2} \text{ lb.} \quad \text{(Eq. 4.9)}$$

Offlead force W_{offdyn}:

$$W_{\text{offdyn}} = \sqrt{\{W_{\text{offSB}}\}^2 + \{W_{\text{offCM}}\}^2} \text{ lb.} \quad \text{(Eq. 4.10)}$$

This combined dynamic horizontal load is then added to horizontal loads due to static crane base inclinations and winds to arrive at the total horizontal design force to be considered for the specified crane rating conditions as:

$$\text{TotalOffload} = W_{\text{offdyn}} + W_{\text{off(FromWind)}} \text{ lb.} \quad \text{(Eq. 4.11)}$$

$$\text{TotalSideload} = W_{\text{sidedyn}} + W_{\text{sideCI}} + W_{\text{off(FromWind)}} \text{ lb.} \quad \text{(Eq. 4.12)}$$

4.3.3 Loads Due to Crane Components

The forces and moments due to the weight of the crane components (boom, gantry, pedestal, etc.) shall be included as loads in the determination of allowable crane ratings and for out-of-service conditions. The vertical loads due to the component weights shall be increased by the acceleration levels given in Table 5 for in-service offboard and onboard lifts and for out-of-service conditions. This accounts for the crane dynamic motion effects acting on the vertical weight of the crane components. The horizontal dynamic effects on the crane components shall also be accounted for by applying the equations in Section 4.3.2.b to the component weight instead of to $\text{SWL} \times C_v$.

4.4 OUT-OF-SERVICE LOADS

When out-of-service, the crane is subjected to loads due to its own weight, the environment, and motions of the platform/vessel. In the out-of-service condition, the crane has no load suspended from the hook. For extreme conditions (hurricane, etc) the crane will be in stowed position, and the crane and boom rest or other stowage arrangement shall be designed to withstand the combination of motions and environmental forces resulting from the most extreme design conditions for the platform/vessel. For lesser operating conditions, the crane may be out-of-service with the boom not stowed. In this condition, the crane must be designed to withstand the combination of motions and environmental forces without benefit of the stowage arrangement. The purchaser shall specify maximum non-stowed and stowed out-of-service conditions.

4.5 WIND, ICE, AND SEISMIC LOADS

4.5.1 Wind

The purchaser may specify desired wind speeds for each lift condition that ratings shall be determined for in-service and for out-of-service conditions. In the absence of purchaser specified information, the wind velocity to use for all in-service conditions shall be 40 mph for seastates up to H_{sig} of 10 ft and 60 mph for seastates up to H_{sig} of 20 ft. The wind velocity to use for out-of-service stowed conditions in absence of purchaser specific information shall be 140 mph. These wind velocities include the effects of elevation and gust loads for the crane location.

The wind pressure acting on the projected area of the crane components and lifted load shall be calculated as:

$$P_{\text{wind}} = 0.00256 \times C_s \times U^2 \qquad \text{(Eq. 4.13)}$$

where

U = wind velocity, mph,

C_s = member shape coefficient,

P_{wind} = wind pressure, psf.

In the absence of other information, C_s shape coefficients are recommended as:

Member Type	C_s
I beams, Angles, Channels	2.0
Square Tube	1.5
Round Pipe	0.8
Flat Sides of Enclosures	1.5

Wind force shall be applied to the boom, lifted load, and other crane components. Wind force shall equal the wind pressure P_{wind} times the projected area (ft^2) of the component. In the absence of specific information, the projected area of the load may be calculated as:

$$\text{LoadProjArea} = (1.33 \times \text{SWL}/200)^{2/3}$$

ft^2 with SWL in lb. (Eq. 4.14)

Table 2—Vertical Velocity for Dynamic Coefficient Calculations

Note: See Commentary for a discussion of how these values were developed.

Supply Boat Velocity V_d (for Preferred and Alternate Methods)	
Load Being Lifted from or Placed on:	**V_d, (ft/sec.)**
Fixed Structure	0.0
Moving Vessel (Supply Boat, Etc.), $H_{sig} < 9.8$ ft	$V_d = 0.6 \times H_{sig}$
Moving Vessel (Supply Boat, Etc.), $H_{sig} \geq 9.8$ ft	$V_d = 5.9 + 0.3 \times (H_{sig} - 9.8)$

Note: H_{sig} shall be in ft when used with the above formulae.

Crane Boom Tip Velocity V_c (for General Method)	
Crane Mounted on:	**V_c, (ft/sec.)**
Fixed Structure	0.0
Tension Leg Platform (TLP)	$0.05 \times H_{sig}$
Spar	$0.05 \times H_{sig}$
Semisubmersible	$0.025 \times H_{sig} \times H_{sig}$
Drillship	$0.05 \times H_{sig} \times H_{sig}$
Floating Production Storage Offloader (FPSO)	$0.05 \times H_{sig} \times H_{sig}$

Note: H_{sig} shall be in ft when used with the above formulae.

Table 3—Onboard Lift Dynamic Coefficients (C_v for General Method)

Crane Mounted on:	Dynamic Coefficient C_v
Fixed Structure	1.33
Tension Leg Platform (TLP)	$1.33 + 0.003 \times H_{sig} \geq 1.4$
Spar	$1.33 + 0.003 \times H_{sig} \geq 1.4$
Semisubmersible	$1.33 + 0.0007 \times H_{sig} \times H_{sig} \geq 1.4$
Drillship	$1.33 + 0.0012 \times H_{sig} \times H_{sig} \geq 1.4$
Floating Production Storage Offloader (FPSO)	$1.33 + 0.0012 \times H_{sig} \times H_{sig} \geq 1.4$

Note: H_{sig} shall be in ft when used with the above formulae.

Table 4— Crane Base Inclinations and Accelerations

Crane Mounted on:	Crane Static Inclination Angle, deg.		Crane Dynamic Horizontal Acceleration, g's
	Heel	Trim	
Fixed Platform	0.5	0.5	0.0
Tension Leg Platform (TLP)	0.5	0.5	$0.007 \times H_{sig} \geq 0.03$
Spar	0.5	0.5	$0.007 \times H_{sig} \geq 0.03$
Semisubmersible	1.5	1.5	$0.007 \times H_{sig} \geq 0.03$
Drillship	2.5	1	$0.01 \times (H_{sig})^{1.1} \geq 0.03$
Floating Production Storage Offloader (FPSO)	2.5	1	$0.01 \times (H_{sig})^{1.1} \geq 0.03$

Note: H_{sig} shall be in ft when used with the above formulae.

1 g = 32.2 ft/sec.^{2}

Table 5—Vertical Dynamic Accelerations to be Applied to Crane Components

Crane Mounted on:	Vertical Acceleration, g's
Fixed Structure	1.0
Tension Leg Platform (TLP)	$1.0 + 0.003 \times H_{sig} \geq 1.07$
Spar	$1.0 + 0.003 \times H_{sig} \geq 1.07$
Semisubmersible	$1.0 + 0.0007 \times H_{sig} \times H_{sig} \geq 1.07$
Drillship	$1.0 + 0.0012 \times H_{sig} \times H_{sig} \geq 1.07$
Floating Production Storage Offloader (FPSO)	$1.0 + 0.0012 \times H_{sig} \times H_{sig} \geq 1.07$

Note: H_{sig} shall be in ft when used with the above formulae.

1 g = 32.2 ft/sec.^{2}

Wind forces acting on the faces of the lifted load shall be added to the other horizontal sideloads and offloads applied at the boom tip. Wind forces acting on the boom and other crane components shall be applied to the boom in the appropriate plane in a direction to be additive to the other horizontal boom loads.

4.5.2 Ice

On cranes where ice or snow accumulation is expected to occur, refer to API RP 2N, latest edition.

4.5.3 Seismic

On fixed structures subject to seismic design loading, cranes shall be designed to meet deck seismic criteria in accordance with the guidelines provided in API RP 2A, 21st Edition 2.3.6.e.2, Deck Appurtenances and Equipment. Specific crane design guidelines are as follows:

a. Cranes and their pedestals shall be designed in accordance with methodologies applied to other significant topside equipment (e.g., drilling rig, flare boom, etc.). Most typically, deck equipment is designed on the basis of a Strength Level Event (SLE) deck appurtenance response spectrum.

b. Consideration shall be given to the uncertainty of the natural period calculations. This is typically handled by broadening or shifting the design spectrums.[13]

c. Due to the very low probability of simultaneous occurrence of a design seismic event at the time of the crane being used for a maximum rated lift, a reduced crane load may be considered simultaneous with the design seismic event. General guidance is that a crane study should be conducted to identify typical offloading loads that will regularly occur during the life of the platform. A load equal to 90% non-exceedance may be used, but should not be less than $^1/_3$ of the rated capacity. In the absence of such a study, a load producing $^2/_3$ of the rated crane overturning moment capacity shall be considered.

d. Seismic analyses shall also consider the no-hook load case. Such analyses help identify components governed by uplift.

e. Seismic analyses shall also consider a design case with the boom in its stowed condition.

f. For SLE analyses, an increase of $^1/_3$ in allowable stresses is permitted.

g. For operational use of a crane in a seismically active area, it is recommended that the crane be stowed on its boom rest when it is not being used.

4.6 GROSS OVERLOAD CONDITIONS

In the case of a gross overload condition, due to the crane hooking a supply boat or other unforeseen event, the crane may fail catastrophically up to and including the possible separation of the entire crane and operator from the foundation. The allowable unit stresses and design factors used in this specification to establish safe working loads for normal conditions do not prevent such a failure in the event of such a gross overload.

At the purchaser's request, the crane manufacturer shall provide failure mode assessments of the principal load carrying components of the crane (boom, loadlines, boomlines, pendants, boom lifting cylinder, king post/pedestal, swing-bearing assembly, and all critical fasteners) to assist the owners in developing suitable risk assessments for operation of the Facility upon which the crane is installed and to evaluate the effects of modifications to the crane on these failure modes (prior to purchase). These failure mode assessments will provide reasonable estimates of the crane's response to a specific set of overload conditions (sidelead, offlead, etc). The crane manufacturer shall provide the purchaser failure mode charts that summarize the failure mode assessments.

[13]Turner, J. Ward, Effenberger, Michael, Irick, Jack, *Seismic Assessment Procedures for Drilling Structures on Offshore Platforms*, SPE 74454, 2002.

The failure mode calculations shall consider failure based on the following:

a. The failure load for all wire rope reeving systems shall be calculated by multiplying the "nominal breaking load" by the number of supporting ropes (parts of line). End connector or reeving system efficiencies shall not be considered.

b. The failure load for all structural steel components shall be calculated utilizing the lesser of the minimum yield stress or the critical buckling stress where applicable, with respect to the appropriate axial cross-sectional area and/or "plastic" bending section properties.

c. The failure load for threaded fasteners under tension shall be calculated by multiplying the specified material minimum tensile stress by the minimum tensile stress area.

d. The failure load for hooks shall be calculated by multiplying the safe working load for the hook by the hook design factor.

Actual lift conditions and equipment condition can differ substantially from the ideal theoretical conditions assumed in failure mode calculations such as these. Under no circumstances should the calculated failure loads be used to justify operating the crane outside of the normal rated load chart limits.

5 Allowable Stresses

5.1 GENERAL

All critical structural components (except as noted in Section 5.3) shall be designed to conform with the allowable unit stresses specified in the AISC *Manual of Steel Construction—Allowable Stress Design*, 9th Edition, when subjected to the loads described in Section 4. For in-service load conditions described in Section 4.2, the basic AISC allowable unit stresses shall be used without benefit of the $^1/_3$ stress increase. For extreme conditions of seismic loads (in-service or out-of-service) or extreme winds (out-of-service only), the AISC $^1/_3$ allowable stress increase can be used.

For structural steels other than those listed in the AISC Specification, compatibility with the AISC allowable unit stresses should be established and documented through discussions with the AISC technical staff.

Critical connecting joints (welded, pinned, or bolted) such as boom splice and heel connections and gantry/mast tension leg members shall be designed to develop 100% of the strength of the connected members. Non-critical connecting joints (welded, pinned, or bolted) shall develop either the load carried by the connected members or the strength of the connected members based on AISC allowables, but in no case less than 50% of the tensile strength of the controlling member. Allowable shear stresses and width-to-thickness ratios shall be in accordance with the applicable provisions of AISC.

5.2 PEDESTAL, KING POST, AND PLATFORM CONNECTION

Pedestals, king posts, and their attachment to the platform shall be designed for the loads defined in Sections 4.2, 4.3, and 4.4 with an additional 1.5 factor applied to the vertical design load and to the horizontal loads due to the vertical design load (offlead and sidelead forces due to the vertical design load). The design moment, thrust, and torque for these components shall be increased accordingly with no allowable stress increase. For low dynamic conditions with the minimum C_v of 1.33 (fixed platform only), this will result in design loads for these components that include the effects of crane dead load, offlead, sidelead, wind, and 2 times rated load (1.33×1.5 factor = 2.0).

The crane manufacturer shall provide the following information:

1. King post or pedestal mounting dimensions at the crane/platform interface.
2. Maximum overturning moment with corresponding axial and radial load at the crane/platform interface.
3. Maximum axial load with corresponding overturning moment and radial load at the crane/platform interface.

For tall king posts and pedestals, additional stiffness may be required to prevent excessive motions of the crane and operator. Excessive motion may cause operator discomfort even if the stress level requirements given above are satisfied.

5.3 EXCEPTIONS TO THE USE OF THE AISC SPECIFICATION

Swing bearings, their bolt connections, and foundation bolts in general are not to be analyzed in accordance with the AISC Specification. The specific design requirements of swing bearings and bolting are presented in Section 9 herein.

5.4 FATIGUE

In the absence of data on projected frequency and magnitude of lifted loads during the expected life of the crane, every critical structural component of the crane shall be designed to withstand a minimum of 25,000 cycles of its onboard lift controlling vertical design load ($C_v \times$ SWL) and associated horizontal loads (offload, sideload, etc.) as defined in Section 4. Allowable stresses may be taken from Appendix K of the AISC Specification. The commentary includes a discussion of the selection of the 25,000 cycle approach.

The design engineer shall consider hot spot stresses in the base metal adjacent to the toe of welds, especially those welds which constitute the main load path in transferring load and which rely on weld length rather than cross-section, i.e., a "bottleneck" in stress flow. This hot spot stress can be defined as that which would be measured by a strain gauge element adjacent to the toe of the weld after stable stress cycles are achieved (or shakedown) during prototype testing. Finite element analysis compatible with this definition may be used to calculate this stress. Fatigue curves such as API RP 2A X or X' or appropriate curves from other sources shall be used to obtain a fatigue life estimate compatible with this definition.

If the purchaser supplies information on expected frequency and magnitude of lifted loads, the design engineer may use either Appendix K of the AISC Specification or the fatigue curves mentioned above to:

a. size structural components to meet fatigue requirements during the design phase, or

b. perform a fatigue analysis to estimate the expected fatigue life of an existing design based on the cyclic information supplied by the purchaser.

5.5 CERTIFICATION

Purchaser shall have confidential access to manufacturer's design calculations, associated drawings and other pertinent information necessary to assure compliance with this specification. The manufacturer shall certify that the crane furnished to this specification meets the material and dimensional specifications used in the calculations.

6 Design Authentication and Testing

6.1 DESIGN AUTHENTICATION

Testing shall be used to verify the design method. The intent is to verify the overall design calculation procedure's accuracy and completeness. This shall be accomplished either by performing a strain gauged load test to 1.33 times the onboard "maximum" rated load or by performing a "heavy lift" test to 2.0 times the same. The results of the test shall prove the design adequacy either by review of measured stresses in the gauged test or by absence of measurable deformation, cracking, or damage in the heavy lift test. The manufacturer shall certify that a prototype, design, or major structural revision to a design has been tested in accordance with either Section 6.1.1 or 6.1.2 as set out below.

6.1.1 Resistance Type Strain Gauge Test

This test shall be performed with the crane subjected to 1.33 times the onboard "maximum" rated load with a side load equal to 2% of the test load. Strain gauges shall be placed in locations to verify that the uniform stress levels in the crane major components are as established in the design calculations. Strain gauges shall also be placed in areas of peak stresses (transitions, connections, etc.) to verify that peak stress levels are acceptable. Deflection of the boom due to sideload shall be measured and limited to 24 in. per 100 ft of boom length. Test loads and boom lengths shall be selected to produce maximum stress levels in all critical structural components.

Care shall be taken to obtain the zero reference reading for the strain gauges with near zero stress levels in the components. This is particularly critical in long boom lengths and other components where dead weight loading is significant. For long boom lengths, multiple support points shall be provided to minimize boom dead weight effects while zeroing the strain gauges. The crane should be exercised by lifting loads prior to strain gauging to allow break-in of the components.

Stresses in different parts of the crane structure shall be measured and evaluated to the following criteria:

a. Uniform stress regions are areas of near-uniform stress where exceeding the yield strength will produce permanent deformation of the member as a whole. In uniform stress regions, a minimum strength margin of 1.5 is required, where a strength margin is computed as the minimum specified member yield strength divided by the measured gauge stress.

b. Groups of gauges shall be placed in uniform stress regions of main members such that their stresses may be combined to determine the member primary axial and bending stress. These shall then be compared to design calculations to verify member stress levels are as predicted. Groups of gauges shall typically be placed to verify boom primary axial and bending stress, gantry leg axial stress, and in any other region where primary axial and bending stress calculations were made during design.

c. Peak stress regions are small areas of high stress surrounded by larger areas of considerably lower stress where exceeding the yield strength will not produce permanent deformation of the member as a whole. The strain gauges in the peak stress location should have a minimum strength margin (minimum specified yield strength divided by measured gauge stress) of 1.1.

6.1.2 Heavy Lift Load Test

This test shall consist of lifting 2.0 times the onboard "maximum" rated load with a corresponding sideload equal to 4% of the maximum rated load. Test loads and boom lengths shall be selected to produce maximum stress levels in all critical structural components. Following the lifts, the crane shall be completely disassembled, including the swing-circle assembly, and subjected to a complete fitness-for-purpose evaluation using an appropriate method of inspection (depending upon the component) chosen from the following:

1. Dye penetrant.
2. Magnetic particle.
3. Radiographic.
4. Ultrasonic.

The acceptability criteria for this test shall be that no critical components exhibit any yielding, buckling, indentations, or surface cracks. Special attention shall be given to bolted and welded connections. Measurements and inspections shall be made before and after the test to determine any differences in condition of critical components. An accompanying requirement of the test shall be that computed stresses under the test loads specified above shall not exceed the AISC Specification allowable unit stresses increased by one-third.

6.2 CERTIFICATION

The purchaser shall have confidential access to the manufacturer's documentation of the results of the selected method of testing. The manufacturer shall certify that the design of the crane furnished has been authenticated in accordance with this specification.

6.3 OPERATIONAL TESTS

In addition to the prototype test and quality control measures established by this specification, each new production crane, at the option of the buyer, shall be tested by the manufacturer at his fabrication facility. The purchaser, or his designated representative, may witness the test. This test procedure, as agreed upon between buyer and manufacturer, is intended to verify safety systems as well as operational systems at rated capacity and full speed. Testing may include, but is not limited to, the following:

1. Auxiliary and main line load tests at various radii.
2. Speed tests for main line, boom luff and swing.
3. Swing and free swing tests.
4. Overload test (1.33 times rated capacity), or as otherwise specified by buyer.
5. Anti two-block tests.
6. Upper and lower boom kick-out tests.
7. Engine functional tests.

7 Critical Rigging Components

7.1 GENERAL

Suspension and hoist systems are comprised of certain rigging equipment. Components of rigging equipment that meet the critical component definition shall be considered critical rigging components and shall comply with the requirements of this section.

7.2 WIRE ROPE

All wire rope used in hoist and suspension systems shall comply with the requirements set out below.

7.2.1 Construction

The crane manufacturer shall specify the wire rope construction to be used for each application (boomlines, loadlines, etc.). The requirements of the latest edition of API Spec 9A shall be the minimum specification for wire rope used on offshore cranes. The ropes shall be suitable for the intended purpose and service life.

7.2.2 Inspection, Maintenance and Replacement (IMR)

The crane manufacturer shall provide IMR procedures for all wire rope used in the crane. The procedures shall comply with the minimum criteria given in API RP 2D.

7.2.3 Wire Rope Load

Wire rope load is defined as the maximum system force generated in the load hoists, boom hoist and suspension systems by the effects of rated load, dead weight, offlead, wind and lifting geometry.

7.2.4 Design Factors

Wire rope design factors shall be determined by multiplying the single wire rope nominal breaking load by the number of supporting ropes and dividing by the wire rope load. Wire rope design factors are intended to account for end connector efficiency and total reeving system efficiency of 80% or greater.

7.2.4.1 Hoist Systems

The design factor of wire rope reeving used in load hoist and boom hoist systems shall not be less than 2.5 times C_v or 5.0, whichever is greater.

7.2.4.2 Suspension Systems

The design factor of standing wire rope used for boom pendants and other support systems shall not be less than 2.0 times C_v or 4.0, whichever is greater.

7.2.4.3 Personnel Hoist System

The design factor of load hoist wire rope when handling personnel shall not be less than 10.

7.3 WIRE ROPE END TERMINATIONS

7.3.1 U-Bolt and Fist Grip Clips

Extreme care should be exercised to assure proper orientation of U-bolt clips. The U-bolt segment shall be in contact with the wire rope dead-end. The orientation, spacing, torquing, and number of all clips shall be in accordance with the crane manufacturer's specifications.

7.3.2 Eye Splice

Eye splices shall have a minimum of three full tucks. Other details of eye splicing shall be specified by the crane manufacturer.

7.3.3 Wedge Sockets

Wedge sockets shall be installed with the live-load-side of the wire rope in line with the wedge socket pin. Wire rope clips used in conjunction with wedge sockets shall be attached to the unloaded (dead) end of the rope as shown in Figure 4. Wedge socket assemblies shall withstand wire rope failure without permanent yield to wedge socket.

7.3.4 Termination Efficiency

Wire rope end terminations shall not reduce wire rope strength below 80% of the wire rope nominal breaking load.

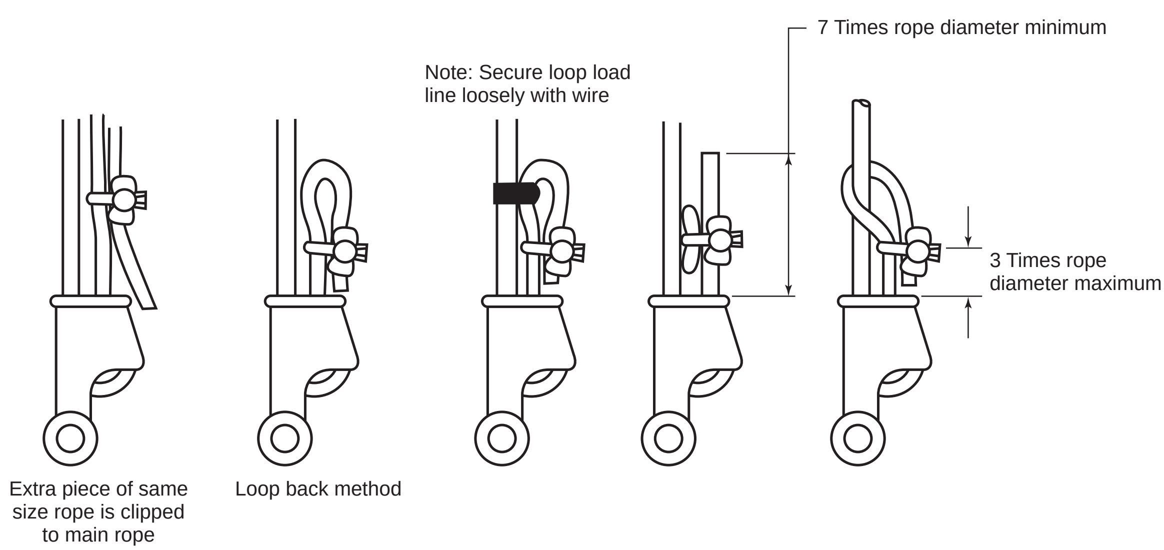


Figure 4—Methods of Securing Dead End of Rope when Using Wedge Sockets

7.3.5 Installation Procedure

Detailed installation procedures for wire rope end termination shall be specified by the crane manufacturer.

7.4 SHEAVES

7.4.1 Requirements

All sheaves that are a part of any crane hoist system shall comply with this specification.

7.4.1.1 Sheave pitch diameter (*D*) to nominal wire rope diameter (*d*) ratio (*D*/*d*) shall not be less than 18 (see Figure 5). A higher *D*/*d* ratio results in a longer fatigue life of the wire rope.

7.4.1.2 Sheave groove contour shall be smooth and free from defects harmful to the wire rope.

7.4.1.3 Sheave groove angle shall taper outward and shall not be less than a 30-degree included angle. Groove flange corners shall be rounded. The rim concentricity and perpendicularity about the rotation axis shall be within tolerances specified by the crane manufacturer.

7.4.1.4 Sheave groove radius for wire rope support shall be sized for the specified wire rope diameter in accordance with Table 6.

7.4.1.5 Sheave bearings shall be individually lubricated through a separate passage. Permanently lubricated bearings are exempt from this requirement.

7.4.1.6 Sheave guards—All sheaves including running blocks shall be provided with guards or other suitable devices to prevent the rope from coming out of the sheave groove.

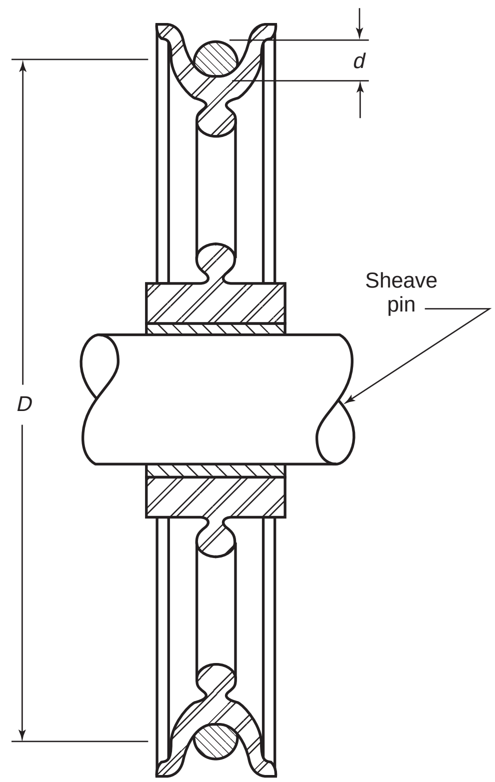


Figure 5—Sheave Dimension

7.5 LOAD BLOCK ASSEMBLIES

7.5.1 Hook Block

The hook block is the main hoist system load block used in main boom lifting operations.

7.5.1.1 Sheave bearings shall be sized to be suitable for the intended service.

7.5.1.2 The weight of the hook block shall be sufficient for the boom length and parts of line specified to prevent slack wire rope when the main hoist drum is unwinding at maximum speed.

7.5.1.3 Cast iron material shall not be used to provide additional hook block weight.

7.5.2 Overhaul Ball Assembly

The overhaul ball assembly is the single part auxiliary hoist system hook and weight assembly used in tip extension lifting.

The weight of the overhaul ball assembly shall be sufficient for the boom length to prevent slack wire rope when the auxiliary hoist drum is unwinding at maximum speed.

Cast iron material is acceptable for use in the ball weight.

7.5.3 Load Block

7.5.3.1 The loads on this component are the maximum onboard, offboard, and personnel handling rated loads.

7.5.3.2 As a minimum, the rating label(s) shall contain the load block maximum non-personnel and personnel rated loads, service temperature and assembly weight. The label shall be permanently affixed to the hook block and overhaul ball. The maximum rated load(s) for dynamic conditions may be added at the option of the purchaser.

7.5.4 Load Hook

The load hook is a fitting incorporated in the hook block and overhaul ball to facilitate connection of the load to the hoist system.

7.5.4.1 The hook material shall be alloy steel and produced as a forging or casting.

7.5.4.2 The fracture toughness of each heat of steel employed in the production of hooks shall be verified by

Table 6—Sheave Groove Radius

Nominal Wire Rope Diameter (in.)		Groove Radius* Min.		Groove Radius* Max.	
in.	mm	in.	mm	in.	mm
1/4	6.5	0.134	3.40	0.138	3.51
5/16	8	0.167	4.24	0.172	4.37
3/8	9.5	0.199	5.05	0.206	5.23
7/16	11	0.232	5.89	0.241	6.12
1/2	13	0.265	6.73	0.275	6.99
9/16	14.5	0.298	7.57	0.309	7.85
5/8	16	0.331	8.41	0.344	8.74
3/4	19	0.398	10.11	0.413	10.49
7/8	22	0.464	11.79	0.481	12.22
1	26	0.530	13.46	0.550	13.97
1 1/8	29	0.596	15.14	0.619	15.72
1 1/4	32	0.663	16.84	0.688	17.48
1 3/8	35	0.729	18.52	0.756	19.20
1 1/2	38	0.795	20.19	0.825	20.96
1 5/8	42	0.861	21.87	0.894	22.71
1 3/4	45	0.928	23.57	0.963	24.46
1 7/8	48	0.994	25.25	1.031	26.19
2	52	1.060	26.92	1.100	27.94

Note: *Groove radii per Wire Rope User's Manual Copyright 1993.

Charpy impact testing. The tests shall be conducted in accordance with ASTM E 23 to yield a minimum average of 25 ft-lb. (34 Joules) on a set of three Charpy test bars. No single value shall be less than 15 ft-lb. (20 Joules). Test temperature shall be the lesser of –40°F (–40°C) or 10°F (6°C) below the lowest design service temperature.

7.5.4.3 Hooks shall be equipped with a latch to retain loose lifting gear under non-lifting conditions. The latch shall be lockable if the hook is to be used for transporting personnel. The latch is not intended to support the lifted load.

7.5.5 Load Block Design Factors

Design factors shall be determined by dividing the load block minimum plastic failure load by the corresponding load block loads. The basic rating design factor shall be 3.0 times C_v, but not less than 4.0. The personnel rating design factor shall not be less than 12.

7.5.6 Design Verification

A prototype design shall be tested to establish the validity of underlying design concepts, assumptions and analytical methods.

7.5.6.1 A proof load of 2.0 times the maximum rating shall be applied without permanent deformation.

7.5.6.2 A plastic failure load shall be confirmed by destructive testing. Differences between actual and minimum material properties shall be taken into account.

8 Boom Hoist, Load Hoist, and Telescoping Boom Mechanisms

8.1 HOISTS

Boom and load hoists shall be approved by the hoist manufacturer for personnel handling and shall be so indicated on their nameplate. Hoists shall also conform to standards of performance and serviceability as set out below.

8.1.1 Brakes

8.1.1.1 Brakes and clutches shall be provided with adjustments, where necessary, to compensate for wear and to maintain adequate force on springs where used.

8.1.1.2 When power operated brakes having no continuous mechanical linkage between the actuating and braking means are used for controlling loads, an automatic means shall be provided to set the brake to prevent the load from falling in the event of loss of brake actuating power.

8.1.1.3 Brakes shall be provided to prevent the drum from rotating in the lowering direction and shall be capable of holding the rated load indefinitely without attention from the operator. Brakes shall be automatically applied upon the return of the control lever to its center (neutral) position. Brakes, which are applied on stopped drums, shall have sufficient impact capacity to hold 1.5 times the maximum torque induced by the hoist pull calculated in accordance with Section 8.1.7 where the rated load "*L*" is defined as the sum of the dead load plus safe working load. The lowest expected coefficient of friction for the brake lining with due consideration of service conditions (humidity, grease, etc.) is to be applied in the design calculation of braking torque capacity, but this coefficient of friction is not to be taken higher than 0.3.

8.1.1.4 Boom or load lowering shall be done only by engagement to the power train. Free-fall lowering of the boom, or load, shall not be permitted.

8.1.1.5 Hoists designed to control descent of a load or boom exclusively through modulation of a friction device shall be able to operate continuously for one hour, raising and lowering the rated load at maximum design speed over a height of 50 ft (15 m). Dwell time between raising and lowering operations shall not exceed three seconds. Coolant flow shall be maintained within limits specified by the hoist manufacturer. At the end of this test, the brake shall have adequate capacity to smoothly stop 110% of the rated load from the maximum design speed in the lowering mode while lowering.

8.1.1.6 Hoists designed to control descent of a load or boom by controlling the speed of the hoist drive input shall be capable of smoothly stopping 110% of rated load from maximum speed while lowering without exceeding the manufacturer's specified temperature limits for any drive train component.

8.1.1.7 Except as noted in Section 8.1.1.8, hoists shall be provided with a dynamic friction braking system that shall actuate automatically to bring the hoist to a smooth stop in the event of a control or motive power loss.

8.1.1.8 Hoists designed to control the descent of a load or boom by controlling flow from a fluid cylinder, or from a fluid drive motor attached directly to the hoist, shall not require dynamic friction braking provided:

a. The control device is connected directly to the lowering outlet port without the use of hoses.

b. The control device requires positive pressure from the power source to release, and it actuates automatically to bring the hoist or cylinder to a smooth stop in the event of a control or motive power loss.

c. The braking system is effective throughout the operating temperature range of the working fluid.

8.1.2 Drums

8.1.2.1 All drum(s) shall provide a first layer rope pitch diameter of not less than 18 times the nominal rope diameter (see Figure 6). The flange shall extend a minimum distance of 2.5 times the wire rope diameter over the top layer of rope unless an additional means of keeping the rope on the drum is supplied (i.e., keeper plates, rope guards, kicker rings, etc.). For example, $1^1/4$ in. (32 mm) diameter main hoist wire shall have $3^1/8$ in. (79.4 mm) clearance over the top layer of rope to the outside edge of the flange.

8.1.2.2 Drum(s) shall have sufficient rope capacity with recommended rope size(s) to operate within the range of boom lengths, operating radii and vertical lifts as agreed to between the manufacturer and the purchaser.

8.1.2.3 No less than five (5) full wraps of rope shall remain on the drum(s) in any operating condition. The drum end of the rope shall be anchored to the drum by an arrangement provided by the crane manufacturer.

8.1.3 Components

Components shall be designed to minimize the likelihood of incorrect use or assembly as set out below.

8.1.3.1 All critical drive components shall have unique spline, keying, or other arrangements to prevent improper installation or interchange of parts.

8.1.3.2 Where the above provisions cannot be met, parts in question shall be clearly marked and specific warnings on interchangeability included in the operating and maintenance manuals.

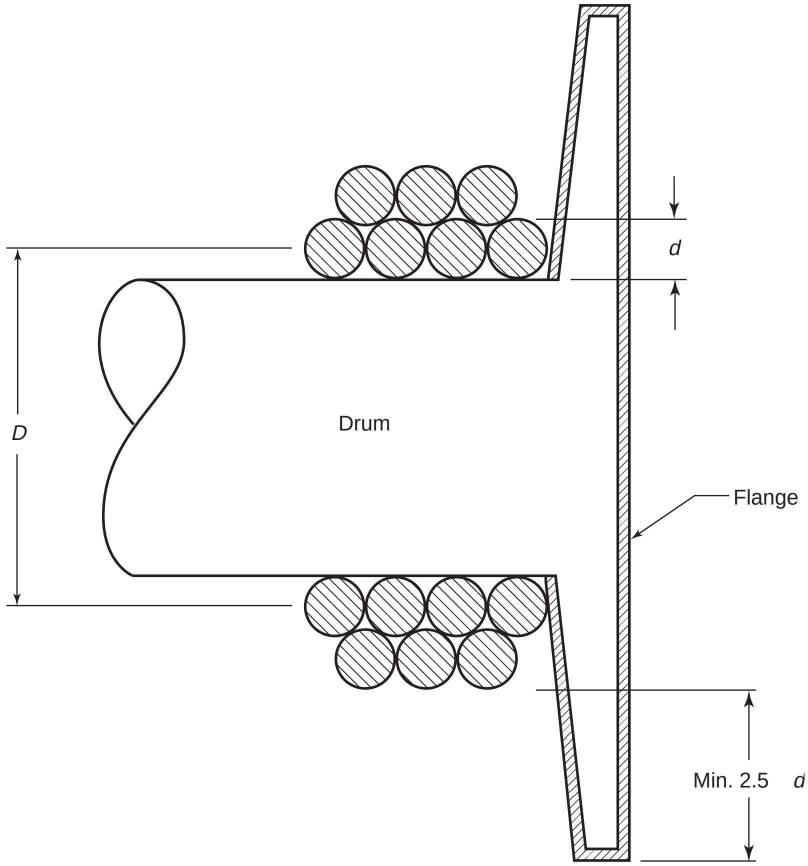
8.1.4 Mounting

The crane manufacturer shall be responsible for the design and testing of hoist foundations, and mounting of hoists.

8.1.4.1 Alignment of hoist components shall be maintained within limits that prevent premature deterioration of gear teeth, bearings, splines, bushings, and any other parts of the hoist mechanism. Where alignment may be disturbed by disassembly, means for field alignment shall be provided.

8.1.4.2 The hoist manufacturer shall provide a mounting procedure that prevents excessive distortion of the hoist base as it is attached to the mounting surface. Flatness of the mounting surface shall be held to tolerances specified by the hoist manufacturer.

8.1.4.3 Distortion of the mounted hoist assembly under load shall not exceed limits specified by the hoist manufacturer. The hoist manufacturer shall establish a procedure for prototype testing and monitoring of distortion under test load. This testing shall be conducted for the maximum rated line pull throughout the recommended range of wire rope departure angles for the hoist.



Note: The flange shall extend a minimum distance of 2.5 times the wire rope diameter over the top layer of rope unless an additional means of keeping the rope on the drum is supplied.

Figure 6—Hoist Drum

8.1.4.4 The attachment of the hoist to the structure shall be sized to resist at least 2.0 times the reactions induced at maximum attainable line pull.

8.1.5 Lubrication and Cooling

8.1.5.1 All hoists shall be equipped with means to check lubricant and coolant levels. The means shall be readily accessible with wire rope in place and shall not require the use of special tools. Maximum and minimum levels shall be clearly indicated.

8.1.5.2 Hoists, which use a circulating fluid for lubrication or cooling, shall be provided with means to check the fluid level while in operation[14].

8.1.5.3 Hoists, which use a closed lubrication system, shall have a fluid capacity of at least 120% of the manufacturer's minimum recommended operating level.

[14]Refer to Section 13.4 of this specification and its sub-sections for requirements.

8.1.6 Flexible Splines and Other Coupling Arrangement Ratings

Flexible splines and other coupling arrangements shall have a design life that is greater than the gear train and/or bearings at rated load and maximum rated speed when operating within the alignment limits of Section 8.1.4 and its sub-sections.

8.1.7 Performance

Boom and load wire rope hoist line pulls that are used for non-personnel and personnel rated loads shall account for reeving system friction losses based on the following formulas:

$$L = PNE$$

$$E = (K^N - 1)/K^S N(K - 1)$$

where

L = rated load,

P = available hoist line pull with load at boom tip,

N = number of line parts supporting load,

E = reeving system efficiency,

K = bearing constant: 1.045 for bronze bushings; 1.02 for roller bearings,

S = total number of sheaves in traveling block and top block or boom point.

8.2 BOOM CONTROL

8.2.1 Hoist Mechanism (Rope Drive)

The boom hoist mechanism is the device used to control the elevation of the boom and support the boom. The boom hoist mechanism shall be capable of the following:

8.2.1.1 Elevating the boom from a minimum boom angle of 0 degrees to the maximum recommended boom angle or upon purchaser request, a lattice boom crane shall be capable of elevating from a minimum boom angle 10 degrees below horizontal to the maximum recommended boom angle.

8.2.1.2 Elevating and controlling the boom and design load (SWL × C_v) within recommended minimum and maximum boom angles.

8.2.2 Boom Control Cylinder

A hydraulic cylinder or cylinders may be utilized to control the elevation of the boom and support the boom as set out below.

8.2.2.1 The cylinder(s) mechanism shall be capable of elevating the boom from a minimum of zero degrees to the maximum recommended boom angle.

8.2.2.2 The boom cylinder(s) shall be capable of elevating and controlling the design load (SWL × C_v) within recommended minimum and maximum boom angles.

8.2.2.3 The boom cylinder(s) shall be capable of supporting the boom and 110% design load (SWL × C_v) within recommended minimum and maximum boom angles.

8.2.2.4 The boom cylinder(s) shall be designed with a 4:1 design factor (ASME Section VIII burst pressure/pressure required to support and raise the boom and a safe working load). The cylinder rod shall have a safety factor against buckling of 2 while holding dead weight plus SWL × C_v. Buckling strength should be calculated by ISO/TS 13725 or other recognized procedure.

8.2.3 Auxiliary Holding Device

A holding mechanism shall be provided for boom support regardless of the type of drive.

8.2.3.1 On rope boom support machines, a ratchet and pawl, or other positive holding device, shall be provided to prevent unintentional lowering of the boom.

8.2.3.2 For hydraulic cylinder boom support machines, a holding device (such as integrally mounted check valves) shall be provided to prevent uncontrolled lowering of the boom.

8.3 TELESCOPING BOOM MECHANISMS

A telescoping boom consists of a base boom from which one or more boom sections are telescoped for additional length (See Figure 1, Types A and B). Extension and retraction may be accomplished through hydraulic, mechanical, or other means. The telescoping cylinder shall have similar design factors to those given in Section 8.2.2.4. For buckling, the combined buckling resistance of the boom sections and cylinder may be considered.

8.3.1 Power Retract Function

The power retract function shall be capable of controlling design load (SWL × C_v) and capable of supporting 110% of the design load (SWL × C_v) within the recommended minimum and maximum boom angles.

8.3.2 Power Extend Function

The powered extend function is not required to extend under load unless otherwise specified by purchaser.

8.3.3 Holding Device

A holding device (such as check valves) shall be provided with telescoping cylinder(s) to prevent uncontrolled movement of the cylinder(s). Hoses shall not be used between the cylinder(s) and the holding device(s).

9 Swing Mechanism

9.1 SWING MECHANISM

The swing mechanism is the means to rotate the upperstructure of the machine. The swing mechanism shall be capable of smooth starts and stops with controllable rates of acceleration and deceleration.

9.1.1 Swing Holding Strength

The swing mechanism shall be designed with sufficient strength and capacity to hold the crane and SWL in position for all radii and boom lengths under the most severe combination of dynamic loadings (SWL times C_v), support structure motions, tilt, and wind conditions as defined in Section 4, for all planned in-service and out-of-service non-stowed conditions.

9.1.2 Swing Rotating

The swing mechanism shall be designed to rotate the crane and SWL with support structure motions, tilt and wind conditions as defined in Section 4 (without C_v and dynamics from the supply boat). The swing mechanism shall also be designed to rotate the crane in the worst non-stowed out-of-service conditions. The swing may be a limiting factor in establishing crane SWL as described in Section 4.1.1.

9.1.3 Parking Brake

A brake or brakes with holding power in both directions shall be provided to restrain movement of the upper-structure under the most severe combination of support structure motions with the SWL loads defined in Section 9.1.2, and for the worst non-stowed out-of-service conditions as listed in Section 4 but not to retard the rotation of the upper-structure during operation.

This brake shall be controllable by the operator at the operator's station and shall be capable of remaining in the engaged position without the attention of the operator.

If the swing is of the automatic type, return of the swing control lever to neutral shall not engage the brake in a manner that abruptly arrests the swing motion. An automatic swing brake, that is incapable of controlled deceleration, shall not be used.

9.1.4 Dynamic Friction Brake

A dynamic friction brake to stop, hold, or retard the rotation motion of the upper-structure may be provided. When provided, it shall be controllable by the operator at the operator's station. It must also satisfy the holding power requirements of Section 9.1.2. The Parking Brake and Dynamic Friction Brake can be the same brake with two methods of actuation.

9.1.5 Optional Swing Parking Mechanism

If specified by purchaser, a device to restrain the movement of the upperstructure of an out-of-service crane, in one or more fixed positions (determined by purchaser), shall be provided.

The purpose of the device is to act as a secondary, redundant, method of preventing crane rotation under mild environmental and deck motion conditions and is not intended to be used during crane operations or to secure the crane during storm conditions. It shall be designed using the Design Parameters in Table 1 for an out-of-service, non-stowed crane.

9.2 SWING-CIRCLE ASSEMBLY

The swing-circle assembly is the connecting component between the crane revolving upper-structure and the pedestal. This component allows crane rotation and sustains the moment, axial, and radial loads imposed by crane operation. The swing-circle assembly may be a roller bearing, ball bearing, hook roller design or a king post design as shown in Figure 1. The swing-circle assembly shall conform to the specifications set out in the following paragraphs.

9.2.1 Design

The following factors shall be used in determining the adequacy of the swing-circle assembly.

9.2.1.1 Design Service Factor

The combination of the following basic loads shall be calculated using the maximum SWL times C_v condition plus dead load.

1. Overturning Moment.
2. Axial.
3. Radial.

These loads may occur simultaneously and result in the maximum stress in the swing-circle assembly and shall be used by the bearing manufacturer in calculating bearing service life and fatigue.

9.2.1.2 Swing-circle Life

Members subjected to repeated stress cycles shall be designed for adequate resistance to structural fatigue degradation. The calculated fatigue life of the assembly shall be substantially in excess of the rolling contact wear (B 10) life as defined by ABMA Standard 9 for ball bearings; ANSI/ABMA Standard 11 for roller bearings; or ISO 281, as applicable.

9.2.1.3 Working Environment

Anti-friction bearings shall be sealed from foreign and marine environmental contamination.

9.2.1.4 Ultimate Strength Design Criteria

The design criteria of the swing-circle assembly[15] including fasteners shall be as follows: The maximum calculated stress is equal to or less than the minimum specified ultimate tensile strength of the material with the dead load plus 3.75 times the maximum SWL times C_v. It shall include the effects of wind, sidelead, and offlead associated with these loads.

[15]An exception is the king post design which is treated as a connective element in Section 5.2 of this specification.

The load, due to external loading on the most heavily loaded swing-bearing fastener shall be calculated by:

$$P = \frac{4 \times M}{N_b \times D} - \frac{H}{N_b}$$

where

M = moment calculated with dead load + 3.75 times SWL times C_v (lb.-ft),

H = dead Axial Load + 3.75 times SWL times C_v (lb.),

D = pitch Circle Diameter of Fasteners (ft),

N_b = number of fasteners,

P = load (lb.) shall not exceed bolt tensile stress area times bolt tensile strength.

The above formula is an approximation of the load on the most heavily loaded fastener which can be affected by crane structure and bearing design. It assumes the crane structure deflection does not induce additional load on the bolt, that the bolt mounting surfaces are parallel to each other, that the bolts are uniformly preloaded to manufacturers specifications and that the bolt circle diameters are relatively close to the ball or roller path diameter. It is the responsibility of the crane manufacturer to verify that the above formula is adequate for the specific crane and bearing design.

9.2.2 Material Properties

The steels employed in the manufacture of the swing-circle assembly shall be selected, tested, and verified as adequate to support the design loads of the crane.

9.2.2.1 Bearing Steels

Steels for rolling elements shall be produced to the minimum requirements of ASTM A 295. Steels for bearing rings shall be selected to produce the desired properties in the finished ring. Cleanliness of bearing ring steels shall conform to the requirements of Method A of ASTM E 45 to the following limits:

Inclusion Category	A	B	C	D
Thin Series	2.5	2.5	2.5	2.0
Thick Series	1.5	1.5	2.0	1.5

Alternate materials of satisfactory properties shall be employed in the design of king post and hook roller assemblies.

9.2.2.2 Heat Treatment of Bearing Raceways

The manufacturer of the swing-circle assembly shall verify adequacy of the mechanical properties of the case and core of the raceways by either performing destructive testing of a representative sample for each prototype design or by performing non-destructive testing of the ring hardness and raceway case hardness depth on each production part.

A report of the material tests shall be compiled indicating the measured values and comparing them with the required design analysis. It shall be the responsibility of the crane manufacturer to review the bearing manufacturer's design assumption and material test data to assure each bearing to be employed on a crane complies with these requirements.

9.2.2.3 Fracture Toughness of Bearing Raceways

The fracture toughness of each heat of steel to be employed in the production of raceways for swing bearings, which are employed as the sole means of restraining separation of the pedestal and the crane, shall be verified by Charpy impact testing. The Charpy tests shall be conducted in accordance with ASTM E 23. The tests shall yield a minimum of 31 ft-lb. (42 Joules) average on a set of three Charpy test bars with no single value less than 20 ft-lb. (27 Joules). The tests shall be conducted at the lesser of –4°F (–20°C) or 10°F (6°C) below the lowest design service temperature. Tests shall be conducted on a sample of the same cross sectional dimensions as the actual ring after heat treatment and shall exhibit the core hardness required of the finished part. Tests shall be conducted on a sample with the same degree of forming reduction and heat treatment as the ring forging. The length of the test bar shall be oriented parallel to the circumference of the ring. The test specimen shall be removed from the sample at a depth as near as possible to the area of the final ring configuration subjected to maximum calculated stress as in Section 9.2.1.4.

9.2.2.4 Welding

All welding on races for the attachment of the bearings to the pedestal or upper frame shall be performed in accordance with the bearing manufacturer's recommended procedures and shall exhibit fracture toughness equivalent to the race base metal. All bearings to be attached to the structure by welding shall be provided with a transition piece of weldable steel. The weld between the hardenable steel and the transition piece shall be subjected to stress relief heat treatment at a temperature not to exceed the tempering temperature employed in the heat treatment of the race. The welds and transition piece shall be designed to have an ultimate strength sufficient to withstand the dead load plus 3.75 times the maximum SWL times C_v. The welds and transition piece shall also be designed to meet the fatigue requirements of Section 5.4 considering the local stresses occurring due to load path and stress concentrations.

9.2.3 Mounting

9.2.3.1 Surface Flatness and Finish

The flatness and surface finish requirements specified by the swing-circle assembly manufacturer shall be maintained for both the revolving upper-structure/bearing and pedestal/bearing mating surfaces.

9.2.3.2 Pedestal Deflection

The maximum deflection of loaded conditions shall be within the limits specified by the swing-bearing manufacturer.

9.2.3.3 Swing-circle Assembly Clearance

If the swing-circle assembly is a ball or roller bearing, clearances permitted before the bearing must be replaced and an approved method of measuring such clearances shall be specified in the crane manual.

9.2.3.4 Roller Path Deflection

If the swing-bearing assembly is a hook roller arrangement, the assembly shall be adjustable to take up clearance. Allowable clearances and method of adjustment shall be specified in the crane manual.

9.2.4 Threaded Fasteners

Threaded fasteners used to connect the swing-circle assembly to the pedestal or upper-structure shall conform to the requirements as set out below.

9.2.4.1 Bolt Spacing

Connecting bolts shall be equally spaced over the 360 degree mounting circumference. One bolt may be omitted for assembly of the swing bearing. The crane manufacturer may use unequal bolt spacing if structural analysis or prototype crane strain gauge instrumented testing is performed to insure the integrity of the bolted connection.

9.2.4.2 Fatigue Life

The fatigue life of threaded connections shall be determined by calculation. Calculations shall be made available to the swing-circle assembly purchaser.

9.2.4.3 Material Properties

The material used in threaded fasteners shall meet requirements of Section 14.5.

9.2.4.4 Pre-stress Levels

Fasteners shall be pre-stressed to a level that will preclude relief of pre-load in the most heavily loaded fastener with the maximum SWL times C_v condition. The level of permanent pre-load is to be determined by the crane manufacturer but is not to exceed 80% of the bolt material yield strength.

9.2.4.5 Fastener Markings

Only fasteners permanently marked with the fastener manufacturer's identification mark and SAE, ASTM, or ISO grade-identifying markings shall be used.

9.2.4.6 Rotation Restraints

Fasteners, which are not accessible for inspection, shall be positively restrained from rotation by nonpermanent means.

10 Power Plant

10.1 GENERAL

The power plant is the prime mover and its auxiliary systems, including the power take-off means and the starting system.

10.1.1 Power Plant Sizing

The power plant minimum output requirements shall be established such that the minimum required hook velocity, $V_{h\min}$ (see Section 4.3.1.a), can be achieved when lifting the corresponding rated load. Plant sizing will be significantly influenced by simultaneous operations (hoist, luff, swing) requirements which shall be specified by the purchaser. In addition to simultaneous operations, power plant and hydraulic component efficiencies shall be taken into consideration when determining the needed power output.

10.1.2 Gasoline Engines

Gasoline engines as prime movers are not permitted.

10.1.3 Pneumatic Prime Movers

Pneumatic prime movers or auxiliary systems, which use flammable gas as the fluid power medium, are not permitted.

10.2 EXHAUST SYSTEMS OF INTERNAL COMBUSTION PRIME MOVERS

10.2.1 Spark Arresting Silencer

Engine exhausts shall be equipped with a spark arresting type silencer.

10.2.2 Exhaust Piping

Exhaust gases shall be piped to the outside of the engine enclosure and discharged in a direction away from the operator.

10.2.3 Exhaust Guards

All exhaust systems shall be guarded in areas where contact by personnel in the performance of their normal duties is possible.

10.3 FUEL TANKS

10.3.1 Neck and Filler Caps

Fuel tanks shall be equipped with filler necks and caps designed to prevent fuel contamination from external sources. Removable caps, where fitted, shall be securely tethered to the filler.

10.3.2 Fuel Tank Drains

Drains shall be provided on all fuel tanks. Drains shall be located to drain the tank below the level of the fuel pick-up.

10.4 HAZARDOUS AREA CLASSIFICATIONS

The latest editions of API RP 500 or API RP 505 shall be used to determine a hazardous area classification. The purchaser shall specify to the manufacturer the classification of the area in which the crane is to be installed. The classification shall consider temporary uses of the area as well as permanently installed equipment. Criteria for power plants installed in such a hazardous area shall be in accordance with Recommended Practice as described in API RP 500 or API RP 505 as it pertains to elimination of ignition sources. Other sources of information are the NEC[16], API RP 14F, and IEEE Std 45[17].

10.5 ISOLATION OF IGNITION SOURCES AND HEATED SURFACES

Isolation of ignition sources and heated surfaces shall be in accordance with the latest edition of API RP 14C, where applicable.

10.6 DIESEL AIR INTAKE SHUT-OFF

Unless otherwise specified by the purchaser, diesel engines shall be equipped with a device to shut the engine intake air in the event of diesel engine runaway[18]. Regulations should be reviewed to insure compliance.

[16]NEC *National Electric Code*, Latest Edition.
[17]IEEE Std 45 *Recommended Practice for Electric Installations on Shipboard*, Latest Edition.
[18]Reference 30 *CFR* 250 Subparts E and F.

11 Controls

11.1 GENERAL

11.1.1 Location

All controls used during the normal crane operating cycle shall be located within easy reach of the operator while at the operator's station.

11.1.2 Automatic Return

Control levers for boom hoist, load hoist, swing, and boom telescope (when applicable) shall return automatically to their center (neutral) positions on release.

11.1.3 Marking and Diagrams

Control operations and functions shall be clearly marked and easily visible by the operator at operator's control station. This can be either by marking each control or by a control arrangement diagram.

11.1.4 Emergency Stop

Provisions shall be made for emergency stop of the crane operations by the operator at operator's control station.

11.1.5 Foot-operated Controls

Foot-operated pedals, where provided, shall be constructed so the operator's feet will not readily slip off.

11.1.6 Control Forces and Movements

When controls and corresponding controlled elements are properly maintained, adjusted, and operated within the manufacturer's recommendations, the forces and movements required to operate the crane within its rated limits shall not exceed the following:

a. Hand Levers—20 lb. (89 N) and 28 in. (350 mm) total travel.
b. Foot Pedals—25 lb. (111 N) and 10 in. (250 mm) total travel.

11.2 POWER PLANT CONTROLS

11.2.1 Power on Board

Controls for normally operating power plants mounted on the crane revolving structure shall be within easy reach of the operator and shall include means to:

1. Start and stop.
2. Control speed of internal combustion engines.
3. Stop prime mover under emergency conditions.
4. Shift selective transmissions.

11.2.2 Remote Power

Controls for operating the power plant shall be conveniently located on the remote power package and shall include the same provisions as Section 11.2.1.

11.3 ENGINE CLUTCH

All cranes with a direct mechanical drive to any crane function shall be provided with a clutch or other effective means for disengaging power. The clutch control shall be within easy reach of the operator at the operator's station.

11.4 CRANE CONTROLS—BASIC LEVER OPERATING ARRANGEMENTS

11.4.1 Basic Single Axis (Four-lever) Operating Arrangement

This section applies to conventional four-lever operating crane controls. It should not be construed to limit the use of, or to apply to, combination controls, automatic controls, or any other special operating control equipment.

11.4.1.1 Basic controls shall be arranged as shown in Figure 7. Controls shown are levers for hand operation.

Table 7—Four-lever Crane Control Function

Control	Operation
1. Swing Control	Push forward to swing toward boom, swinging left for right side operator position or swinging right for left side operator position. Center (neutral) to free swing. Pull back to swing away from boom.
2. Auxillary Hoist Control (Auxillary)	Pull rearward to hoist Center (neutral) to hold load. Push forward to lower.
3. Main Hoist Control	Pull rearward to hoist. Center (neutral) to hold load. Push forward to lower.
4. Boom Hoist Control	Pull rearward to raise boom. Center (neutral) to hold boom position. Push forward to lower boom.
5. Boom Telescope* (More than one lever may be provided)	Pull rearward to retract. Center (neutral) position to hold length. Push forward to extend.

Note: * Where applicable.

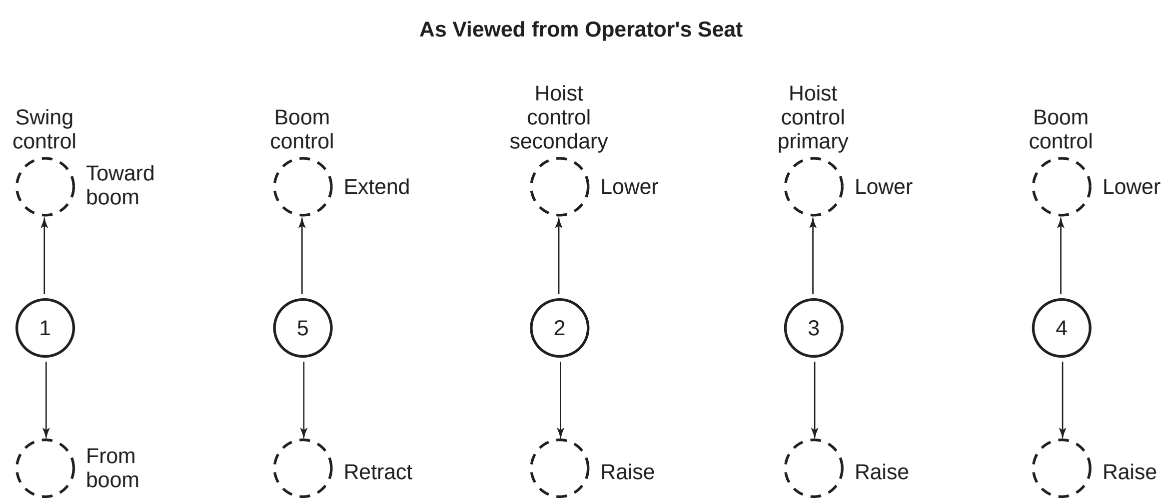


Figure 7—Basic Four-lever Crane Control Diagram

11.4.1.2 Controls for all other functions, such as auxiliary drums and throttles, shall be positioned to avoid operator confusion and physical interference. Nothing in this specification precludes the use of additional controls subject to the foregoing requirements.

11.4.1.3 All basic controls shall operate as specified in Figure 7 and the function chart as shown in Table 7.

11.4.2 Basic Dual Axis (Two-lever) Operating Arrangement

This section applies to conventional two-lever operating crane controls. It should not be construed to limit the use of, or apply to, combination controls, automatic controls, or any other special operating control equipment.

11.4.2.1 Basic controls shall be arranged as shown in Figure 8 or 9. Controls shown are levers for hand operation.

11.4.2.2 Controls for all other functions, such as auxiliary drums and throttles, shall be positioned to avoid operator confusion and physical interference. Nothing in this specification precludes the use of additional controls subject to the foregoing requirements.

11.4.2.3 Basic controls shall operate as specified in Figure 8 or 9 and the function charts as shown in Table 8 or 9.

12 Cabs and Enclosures

12.1 GENERAL

Insofar as practical, all cabs and enclosures shall be constructed to protect the upper-structure machinery, brakes, clutches, and the operator's station from the weather. Cranes without cabs or enclosures to protect the operator, upper-structure machinery, brakes, and clutches shall be adequately protected from the corrosive influence of the offshore environment.

12.2 WINDOWS

All windows shall be of safety glass or equivalent. Windows shall be provided in the front and both sides of the operator's cab for visibility forward and to either side. Visibility forward shall include a vertical range adequate to cover the boom point and load at all times. The front window may have a section that can be readily removed or held open if desired. If the section is removable, storage space shall be provided. If the section is of the type held in the open position, it shall be secured to prevent inadvertent closure. The lower portion of the front window shall have a grating or other means to prevent the operator from falling through. If the cab is equipped with an overhead window, a grating or other protection should be placed over the window to prevent debris from falling on the operator.

12.2.1 Window Wipers and Washers

If specified by the purchaser, sufficient window wipers and washers shall be provided as required to ensure a clear view of the boom tip and load at all times.

12.3 DOORS

All cab or enclosure doors, whether of sliding or swinging type, shall be adequately restrained from inadvertent opening or closing while the machine is in operation. The door adjacent to the operator, if of the sliding type, shall slide rearward to open and, if the swinging type, shall open outward. A clear passageway shall be provided to the exit door nearest the operator's station.

12.4 CAB ACCESS

Suitable hand holds or steps shall be provided for access to, and exit from, the operator's cab or enclosure. Handholds shall be provided in accordance with ANSI A1264.1.

12.5 PLATFORMS AND WALKWAYS

Principle walking surfaces shall be an anti-skid type. Outside platforms, if furnished, shall be provided with guardrails in accordance with ANSI A 1264.1. Two intermediate railings shall be provided in locations where toe boards are not required. All walkways and platforms used to reach operator's station shall have a minimum width of 30 in. (760 mm), unless otherwise specified by the purchaser.

12.6 RIGGING ACCESS

Where necessary for rigging or service requirements, a ladder or steps shall be provided for access and shall conform to the requirements of ANSI A14.3. Where necessary, areas of cab roof or enclosure shall be capable of supporting the weight of a 200-lb. (90-kg) person without permanent deformation.

12.7 NOISE LEVEL

Unless otherwise specified by the purchaser, sound levels associated with the crane shall comply with OSHA 1910.95[19].

13 Miscellaneous Requirements and Equipment

13.1 BOOM EQUIPMENT

The following criteria apply to the boom.

[19]OSHA 1910.95 *Occupational Noise Exposure*.

Table 8—Two-lever Crane Control Function (Option 1)

Control	Operation
Swing Control	Push to the left to swing left. Center (neutral) to free swing. Push to the right to reverse action or to swing right.
Auxillary Hoist	Pull rearward to hoist Center (neutral) to hold load. Push forward to lower.
Boom Control	Pull rearward to raise boom. Center (neutral) to hold boom position. Push forward to lower boom.
Main Hoist	Push to the left to hoist. Center (neutral) to hold load. Push to the right to lower.
Boom Telescope* (More than one lever may be provided)	Pull rearward to retract. Center (neutral) to hold length. Push forward to extend.

Note: *Where applicable

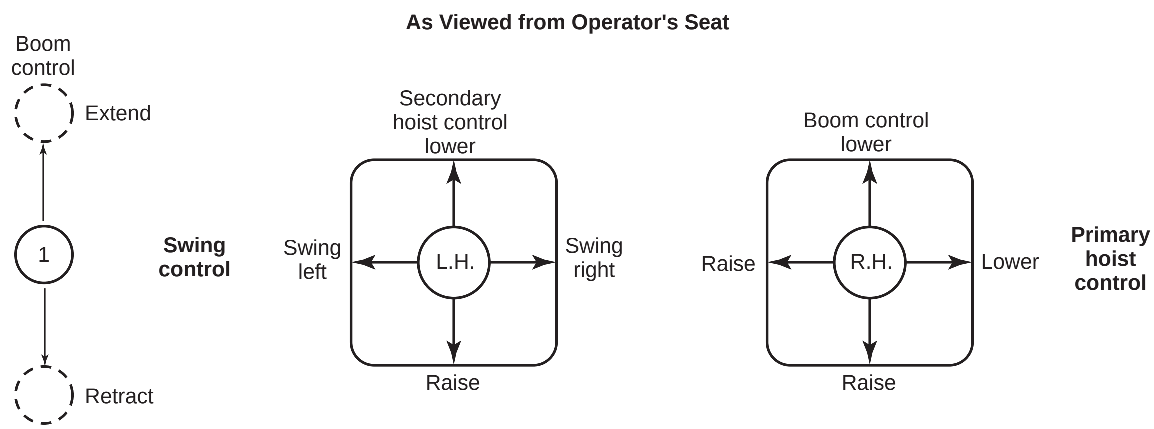


Figure 8—Basic Two-lever Crane Control Diagram (Option 1)

13.1.1 Boom Angle Limiters and Shut-off Devices

A boom hoist limiter or shut-off shall be provided to automatically stop the boom hoist when the boom reaches a predetermined high angle. An optional low angle limiter or shut-off may also be provided.

13.1.2 Resistance to Falling Backward

Boom stops shall be provided to resist the boom falling backwards in a high wind or sudden release of the load. Designs for boom stops include:

a. A fixed or telescoping bumper.
b. A shock absorbing bumper.
c. Hydraulic boom elevation cylinder(s).
d. Auxiliary tips shall be restrained from backward overturning.

13.1.3 Marking and Labeling

Booms, boom sections and auxiliary tips shall be permanently identified.

13.1.4 Boom Indicators

Indicators shall be provided per the following:

13.1.4.1 A boom angle or load radius indicator, readable from the operator's station, shall be provided.

Table 9—Two-lever Crane Control Function (Option 2)

Control	Operation
Swing Control	Push to the left to swing left. Center (neutral) to free swing. Push to the right to reverse action or to swing right.
Auxiliary Hoist* Main Hoist*	Pull rearward to hoist Center (neutral) to hold load. Push forward to lower.
Boom Control	Pull rearward to raise boom. Center (neutral) to hold boom position. Push forward to lower boom.

Note: *When separate main and whip hoists are provided, a selector switch for either may be fitted adjacent to the right hand control lever. The selection of "auxiliary" or "main" shall be possible only when both levers are in their neutral position.

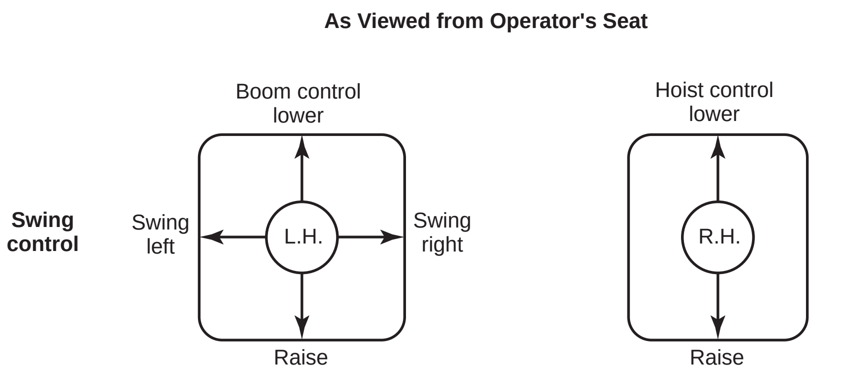


Figure 9—Basic Two-lever Crane Control Diagram (Option 2)

13.1.4.2 A boom length indicator, readable from the operator's station, shall be provided for telescoping booms, unless the load rating is independent of the load radius.

13.1.4.3 A load indicating or load moment device may be provided as optional equipment.

13.2 GUARDS FOR MOVING PARTS

Guards shall be provided per the following requirements.

13.2.1 Components to Guard

Exposed moving parts such as gears, set screws, projecting keys, chains, chain sprockets, and reciprocating or rotating parts, which may constitute a hazard under normal operating conditions, shall be guarded.

13.2.2 Guard Fasteners and Strength

Guards shall be securely fastened and shall be capable of supporting, without permanent deformation, the weight of a 200-lb. (90 kg) person unless the guard is located where it is impossible to step on it.

13.2.3 Warning Signs Instead of Guards

If a guard is impractical, it is the responsibility of the manufacturer to warn by means of an appropriate sign. This sign should be designed and installed in accordance with SAE J115 consistent with physical limitations on size and location.

13.3 CLUTCH AND BRAKE PROTECTION

All friction brakes and clutches shall be provided with rain guards. Pins, shafts, and bolts in clutch and brake linkages shall be corrosion resistant.

13.4 LUBRICATING POINTS AND FLUID FILLS

13.4.1 General

Lubricating points on all parts shall be accessible without the necessity for removing guards or other parts. Fluid fill points (fuel, coolant, hydraulic fluid, etc.) shall be located in areas that are easily accessible and will not collect fluid spills.

13.4.2 Fluid Level Indicators

Fluid level indicators should follow the guidelines set forth in SAE J48.

13.4.3 Lubrication Charts, Symbols, and Codes

Lubrication charts shall be furnished by the manufacturer. For preferred symbols and color codes for fluid fills, see SAE J223.

13.5 HYDRAULIC AND PNEUMATIC LINE PROTECTION

Exposed lines subject to damage shall be protected as far as practical.

13.6 USE OF ENVIRONMENTALLY SENSITIVE MATERIALS

Paint containing lead or chromate shall not be used on the crane or any of its components. Asbestos shall not be used on the crane or any of its components.

13.7 ANTI TWO-BLOCK

Means shall be provided to protect hoist ropes, structural components and machinery from damage that may occur when two sheave groups (e.g., load block and boom tip) come into contact as the hoist cable is drawn in. A control override device or proximity-warning device may be used. Stalling of the hoist drum is acceptable where damage or loss of control would not result.

13.8 PERSONNEL EMERGENCY LOAD LOWERING

Unless otherwise specified by the purchaser, at least one hoist drum shall be provided with a means of lowering personnel in the event of power failure or control system failures. Means shall provide controlled lowering and stopping of the drum under all load conditions.

The controls shall be arranged in a manner that will prevent inadvertent engagement. An alternate power source independent of the crane may be used. An instruction plate giving detailed instructions shall be provided at the operator's station for all procedures.

13.9 MISCELLANEOUS EQUIPMENT

13.9.1 Toolbox

A toolbox may be provided for storing tools and lubricating equipment. If provided, it shall be secured permanently to the crane.

13.9.2 Hydraulic Circuit Pressures

Means shall be provided for checking the manufacturer's specified pressure settings in each hydraulic circuit.

13.9.3 Hazardous Area Classification

Electrical components on the crane or remote power plants used in areas classified hazardous shall comply with the criteria in Section 10.4.

13.9.3.1 Components on the boom shall be rated for the most hazardous area that can be accessed by the boom.

13.9.3.2 The purchaser shall specify to the manufacturer the classification of the area in which the crane will be installed.

13.9.3.3 The classification will consider temporary uses of the area as well as permanently installed equipment.

13.9.4 Audible Warning Device

When specified by the purchaser, an audible signal device shall be provided. The control(s) for the device shall be within easy reach of the operator at the operator's station.

13.9.5 Spillage Containment

All machinery areas, which are subject to liquid leakage, shall be provided with a containment system. The containment area (well) shall have a minimum lip height of 2.0 in. (50 mm) and be provided with a means for draining. Government regulations should be reviewed for applicability.

14 Material Requirements for Structural Components

14.1 MATERIALS

Materials used in the manufacture and fabrication of all critical components of the crane shall comply with the manufacturer's design requirement for strength and fracture toughness.

14.1.1 Metals

The design requirement shall define the following properties of metallic materials:

a. Chemical Composition Limits.
b. Heat Treatment Condition.
c. Mechanical Property Limits including yield strength, tensile strength, elongation, fracture toughness and ductility.

14.1.2 Testing

The design requirement specifications shall detail the methods of testing to verify the specified properties are present in the as-manufactured or as-fabricated condition. To the extent possible, all materials shall be purchased to specifi-

Table 10—Acceptable Criteria Based on ASTM Radiographic Standards

Type of Discontinuity	ASTM E 446	ASTM E 186	ASTM E 280
Category A (Gas Porosity)	Severity Level 3	Severity Level 2	Severity Level 2
Category B (Sand and Slag)	Severity Level 2	Severity Level 2	Severity Level 2
Category C (Shrinkage)	Type CA, Level 2 Type CB, Level 2 Type CC, Level 1 Type CD, Level 1	Type 1, Level 1 Type 2, Level 2 Type 3, Level 1	Type 1, Level 1 Type 2, Level 1 Type 3, Level 1

Note: All discontinuities in Categories D, E, F and G are unacceptable.

cations of recognized standardization organizations such as those listed in Section 2.1.

14.1.3 Wire Rope

Refer to Section 7.2 and its sub-sections for wire rope requirements.

14.2 TRACEABILITY

Traceability of materials for critical components and parts shall be achieved through a systematic program of serialization and identification, indexed to process, inspection, and test records of controlled manufacturing procedures. The manufacturing procedures shall be in sufficient written detail to permit duplication of the original processing at any time within the record retention period specified in Section 1.5. Documentation of material origins shall be that of the basic producer in lieu of certifications prepared by third-party material suppliers. In the absence of supporting documentation, materials shall not be employed in fabrication until the manufacturer conducts or has conducted tests and examinations to verify compliance with design requirements. Critical structural components shall not be produced from materials which lack supporting documentation to verify the properties are as specified in the design and manufacturing specifications.

14.3 FRACTURE TOUGHNESS

All critical components of the crane shall exhibit Charpy-impact energy values assuring the transition from brittle-to-ductile fracture is at least 10°F (6°C) below the lowest design service temperature. The design service temperature shall be indicated on the nameplate. Other appropriate fracture control plans considering toughness, allowable flaw size, and inspection requirements may be employed if desired. If fitness-for-purpose criteria are employed, the details of the analysis shall be documented for examination, upon request, by the purchaser.

14.4 CASTINGS

14.4.1 Prototype Castings

The validity of the casting procedure for all critical component castings shall be verified by conducting examinations and tests on the first lot cast and/or each change in pattern design or pouring practice. Destructive testing and/or radiographic examinations supplemented by other nondestructive examinations are considered appropriate for this purpose. If radiography is employed, the source of radiation for examination of casting sections less than 2.0 in. (50.8 mm) in thickness shall be from an X-ray generator or from Iridium 192 isotopes. The prototype evaluation shall demonstrate the ability of the casting procedure to consistently produce critical component casting soundness not less than the radiography standards of Table 10.

14.4.2 Production Castings

The method of nondestructive examination and the acceptance criteria for examination of the critical component production castings shall be established by the manufacturer. The manufacturer shall consider material properties, environmental exposure, and stress level(s) in critical areas of the casting. The extent of the examination shall be adequate to assure castings possess soundness adequate for the intended purpose; i.e., examine all critically stressed areas.

14.4.3 Thermal Treatment

All castings for critical components shall be subjected to a normalize and temper, quench and temper, or stress relief heat treatment after shake-out and cooling to ambient temperature. The tempering and stress relief temperatures employed shall be appropriate to the alloy content and strength level required of the component, but shall not be less than 1,100°F (593°C).

14.5 FASTENERS

Threaded fasteners subject to static and/or dynamic tensile loading (other than pre-load) employed in joining of critical components of the crane shall meet the requirements of ASTM A 320/A 320 M. The specific grade of material shall be selected to meet strength requirements, fracture toughness, and corrosion resistance of the service environment. Where bolts of higher strengths than permitted by ASTM A 320/A 320M are desired, the materials shall meet the specifications in SAE J429 and ANSI B18.2.1. Qualification of the higher strength material shall be by testing of two threaded fasteners from each heat of steel for proof of mechanical strength, hardness, and Charpy impact energy values. The minimum average impact energy obtained from a set of three tests shall be 30 ft-lb. (40.6 Joules) with no single test value less than 22 ft-lb. (29.8 Joules). Test temperature shall be the lower of 0°F (–17.8°C) or 10°F below the lowest design service temperature.

14.6 PLATE

Critical structural elements fabricated from plate, which must transfer loads through the thickness or the short transverse dimension of the plate, shall be ultrasonically inspected in accordance with Acceptance Standard Level B in ASTM A 578/A 578M. They shall be tested for resistance to lamellar tearing in accordance with the procedures and requirements of Supplementary Requirement S-4 of API Spec 2H[20] or ASTM A 770/A 770M.

15 Welding of Critically Stressed Components

15.1 STANDARDS

All welding procedures for joining of structural load bearing or load transfer members of the crane and the performance of welders employing these procedures shall be qualified in accordance with a recognized standard such as the American Welding Society AWS D1.1 (latest edition).

15.2 WELDING PROCEDURES

A written procedure specification shall be prepared for all welding. Pre-qualified procedures as defined in AWS D1.1 are acceptable only for joining the materials using the consumables, joint configurations, and procedure limits specified therein. The welding of materials or use of procedures other than those defined by the AWS specifications shall be qualified by testing a sample weld produced in accordance with a written procedure and tested in accordance with the standard used in Section 15.1.

[20]Supplementary Requirement S-4 of API Spec 2H *Carbon Manganese Steel Plate for Offshore Platform Tubular Joints.*

15.3 WELDER PERFORMANCE

The performance of welders shall be verified by destructive testing or by radiographic examination. Radiographic examination shall be limited to groove welds using the shielded metal-arc, submerged-arc, gas tungsten-arc, gas metal-arc (globular arc, spray arc or pulsating arc only) and flux cored arc processes. The performance of welders employing short-circuiting (short-arc) gas metal arc welding processing shall be qualified by destructive testing only.

15.4 WELDING PROPERTIES

The strength and fracture toughness of welds and heat-affected zones in critical components shall meet the minimum specified design requirements of the materials being joined. Mechanical testing shall be conducted during procedure qualification to verify that the required properties of the weld and heat-affected zones are attained by the controls outlined in the welding procedure specification.

16 Nondestructive Examination of Critical Components

16.1 NONDESTRUCTIVE EXAMINATION PROCEDURES

The manufacturer shall establish written nondestructive examination procedures for the examination of critical components of the crane. The procedures shall consider the stage of manufacture in which the examination is to be performed, the accessibility to examination methods, and the configuration of the component to be examined. These procedures shall be employed by the manufacturer's personnel and/or any contract nondestructive examination personnel utilized by the manufacturer.

16.2 NONDESTRUCTIVE EXAMINATION PERSONNEL QUALIFICATIONS

All nondestructive examination personnel employed or contracted for by the manufacturer shall be qualified in accordance with ASNT Recommended Practice SNT-TC-lA at Level II proficiency. For ultrasonic examination of tubular members, the manufacturer shall verify the validity of the procedures and competency of personnel in accordance with the latest edition of API RP 2X.

16.3 MINIMUM EXTENT OF NONDESTRUCTIVE EXAMINATION

The manufacturer shall identify all critical components of the crane. These components shall be subjected to nondestructive examinations in accordance with a recognized workmanship standard or, at the option of the manufacturer, by a written examination procedure and acceptance criteria developed in a fitness-for-purpose fracture control plan. The extent of nondestructive examination of non-critical components is also the responsibility of the manufacturer.

16.4 EXAMPLES OF WORKMANSHIP STANDARDS

Table 11 shows examples of components that may be considered critical in some crane designs; some recognized procedures for conducting nondestructive examinations, and acceptance criteria representing workmanship standards. The manufacturer shall be responsible for developing a similar scheme (with appropriate acceptance criteria) from consideration of the specific crane design, criticality of the component, and applicable nondestructive examination methods. Acceptance criteria based on fitness for-purpose evaluations shall consider applied and residual stresses, material properties, environmental exposure, and the limitations of the selected nondestructive examination method for detection and evaluation of imperfections.

17 Marking

Offshore cranes that meet all the requirements of this specification shall have a permanent nameplate of stainless steel or other metallic material of equal corrosion resistance in a marine environment affixed to the structure in a conspicuous location protected from damage and disfigurement. The nameplate shall provide the date manufactured, manufacturer's model number, design service temperature, manufacturer serial number, and manufacturer's identification. The nameplate shall also identify the Quality Program used during the crane manufacture as "Produced Under ___________ Quality Program." The required information shall be imprinted in legible raised or stamped lettering not less than $^1/_8$ in. (4 mm) high.

Monogram holders may apply the API Monogram to the nameplate as shown in Appendix D. For information on the API Monogram, see Appendix D.

Table 11—Workmanship Standard Examples

Component	Method of Inspection	Acceptance Criteria
WELDMENTS		
Base pedestal, upper load structures, booms fabricated of plate elements, fabricated drums	AWS D1.1 6 A,B,D – G (radiographic inspection, ultrasonic inspection) ASTM Volume 03.03	AWS D1.1 6.10, 6.12, 6.12.2, 6.12.3, 6.13
Booms fabricated of tubular elements, weld thickness less than $^3/_8$ in. (9.5 mm)	AWS D1.1 6.14.4, ASTM E 709	AWS D1.1 6.10, 6.12.2
Weld thickness $^3/_8$ in. (9.5 mm) and over	API RP 2X, ultrasonic, AWS D1.1	API RP 2X 7.10, AWS D1.1, 6.13
CASTINGS		
Drums, hook pin frames, sheave block housings, reeving fittings	ASTM E 709, AWS D1.1	ASTM E 125 Table 1 Types of, Discontinuities, 6.10, 6.12.2
WROUGHT PRODUCTS		
Forgings hook pin frames, load hooks, reeving fittings	ASTM E 709, AWS D1.1	ASTM E 125 Table 1 Types of Discontinuities, 6.10, 6.12.2
Bar stock boom pins, gantry, bridle pins, hook pins, shafts	ASTM E 709, AWS D1.1	ASTM E 125 Table 1 Types of Discontinuities, 6.10, 6.12.2

APPENDIX A—EXAMPLE LIST OF CRITICAL COMPONENTS

The following is an example list of some, but not all, components of a crane that may be classified as "critical" by the definition contained herein. The designer and/or manufacturer of each crane shall be responsible for developing a complete list of critical components for each individual design. See Figures 1 and 2 for nomenclature.

Critical Mechanical Components

- All linkage between the brake control element and the component to be controlled
- Hoist and slewing brake systems
- Drums, shafts, and gears of hoisting and slewing systems
- Slewing rings on Types A, B, C, and D cranes

Critical Structural Components

- Fasteners in critical load path of all critical components
- Boom chord members
- Boom section connection components
- Boom foot pins
- Boom jib section and connection components
- Primary load members of gantries, masts, and A-frames
- Load transfer members of the rotating upper-structure including fasteners
- King posts in Type E cranes
- Pedestals and swing-circle transition pieces of Types A, B, C, and D cranes

Critical Rigging Components

- All running wire ropes in hoist systems
- All standing wire ropes in load restraint and support systems
- Hook block assembly
- Overhaul ball or weight assembly
- Wire rope dead-end connection devices
- Floating harness or bridle assemblies
- Wire line sheaves and sheave shafts

APPENDIX B—COMMENTARY

Note: The paragraph numbering of Appendix B corresponds to the text of this specification. For example, B.4.3 titled *In-service Loads* corresponds to Section 4.3 of this specification, titled *In-service Loads*.

B.4.1 RATED LOAD

The load rating system for pedestal mounted cranes addresses the unique problems of these machines. Being attached to a rigid base, pedestal cranes are susceptible to operational overloads during on-platform use. In addition, the high-speed hoisting capabilities required for offboard operations increase the impact potential during onboard lifts. A minimum vertical design load has therefore been established at 133% of the rated load for fixed platforms. Offboard operations involve impact factors larger than onboard operations. For offboard lifts, the vertical load factor C_v shall be at least as large as for onboard lifts.

The minimum vertical design factor of 1.33 as defined in this specification is intended to apply to onboard lifts with a crane mounted to a bottom-supported structure. Somewhat higher minimum vertical design factors are defined for floating structures depending on their size and tendency to exhibit significant listing or wave induced motions. Ratings for cranes on floating platforms and vessels must include the effects of crane vessel dynamic motion and vessel static angles (list or trim). These effects will affect the C_v vertical design factor as well as offlead and sidelead forces.

The treatment of dynamic effects in this specification represents the Committee's efforts to establish crane ratings that minimize the probability of failure in a dynamic environment. The Committee carefully studied the state-of-the-art in structural dynamics analysis and found that very sophisticated theoretical modeling techniques do exist in the literature. However, it is obvious that dynamic load charts produced from the most sophisticated computational methods available would be of no more value to an offshore crane operator than one generated from simplified assumptions since the operator must react to rapidly changing environmental conditions. For this reason and others, the single degree-of-freedom (DOF) mathematical model was adopted. Although the rating method adopted here will make offshore crane lifts safer, it has no provisions for dealing with the extreme dynamic overloads such as accidental connection to a supply vessel or stopping a falling load, etc. Such overloads can be unbounded and cannot be computationally incorporated into a rating chart.

B.4.1.2 Personnel Rated Loads

To provide a substantially increased structural safety margin for personnel handling, the rated load for these operations is established at one-third ($^1/_3$) of the non-personnel rated load. This provides a factor of at least 4.0 against allowable stresses and at least 6.0 against yield for structural components. Increased design factors for wire rope strength are also provided.

B.4.3 IN-SERVICE LOADS

In-service loads include vertical design loads (SWL times a design factor), horizontal loads (offlead and sidelead), and environmental loads (typically wind). Three methods are given to determine the loads acting on a crane.

Vessel Specific Method. For floating crane installations, the Vessel Specific Method is the preferred method. It includes the effects of boom tip motions for the specific vessel the crane is installed on. Vessel motions analysis should be used by the purchaser or his representative to predict boom tip motions, velocities, and accelerations with the boom at typical offboard lift location(s). These motions may then be used to develop V_c and horizontal boomtip accelerations for specific seastates.

General Method. The General Method is used for both fixed platform and floating crane installations. For fixed platforms, it results in similar design factors as in the previous API Spec 2C. For floating crane installations where Vessel Specific motions and loadings are not known, it provides the best alternative method. The dynamic accelerations and loads presented for floating crane installations in the General Method were determined based on studies of crane motions on various representative vessels of each type (TLPs, spars, drillships, etc). Table B.4.3.1 summarizes the general sizes and types of vessels from which the motions were developed.

Table B.4.3.1—General Method—Vessel Information

Type of Floating Crane Installation	Length by Width of Representative Installations	Approx. Vessel Displacement, tons
Tension Leg Platform	150' × 150' to 300' × 300'	12,000 – 27,000
Spar	90' to 130'	120,000 – 240,000
Semisubmersible	200' × 260' to 280' × 400'	30,000 – 65,000
Drillships & FPSOs	75' × 500' to 200' × 900'	70,000 – 220,000

Note: 1 ton = 2000 lb.

Table B.4.3.2—General Method Sample Design Value Calculations

TLP, Spar

H_{sig}, m	H_{sig}, ft	Table 2 Offboard V_c, ft/sec.	Table 3 Onboard C_v	Table 4 Dynamic Horiz. Accel. g's
0	0	0.00	1.40	0.03
1	3.3	0.17	1.40	0.03
2	6.6	0.33	1.40	0.05
3	9.8	0.49	1.40	0.07
4	13.1	0.66	1.40	0.09
5	16.4	0.82	1.40	0.11
6	19.68	0.98	1.40	0.14

Semi

H_{sig}, m	H_{sig}, ft	Table 2 Offboard V_c, ft/sec.	Table 3 Onboard C_v	Table 4 Dynamic Horiz. Accel. g's
0	0	0.00	1.40	0.03
1	3.3	0.27	1.40	0.03
2	6.6	1.09	1.40	0.05
3	9.8	2.40	1.40	0.07
4	13.1	4.30	1.45	0.09
5	16.4	6.72	1.52	0.11
6	19.68	9.68	1.60	0.14

Drillship, FPSO

H_{sig}, m	H_{sig}, ft	Table 2 Offboard V_c, ft/sec.	Table 3 Onboard C_v	Table 4 Dynamic Horiz. Accel. g's
0	0	0.00	1.40	0.03
1	3.3	0.54	1.40	0.04
2	6.6	2.18	1.40	0.08
3	9.8	4.80	1.45	0.12
4	13.1	8.61	1.54	0.17
5	16.4	13.45	1.65	0.22
6	19.68	19.37	1.79	0.27

The resulting floating crane vessel design accelerations in the specification provide representative levels of loading for the various types of vessels. However, there is no guarantee that these loadings are appropriate or adequate for a given floating crane installation. The best crane ratings for a given installation will be determined using the Vessel Specific approach with motions and information for the crane locations on that particular vessel.

Table B.4.3.2 gives sample calculations of the various design values for the General Method versus significant waveheight.

Default Dynamic Method. The third method for establishing a dynamic coefficient, as described in Section 4.3, is adoption of a uniform factor for all offboard lifts. This has substantial operational advantages in simplifying rating charts and their use. The dynamic coefficient must be large enough to account for the most severe operating sea conditions, yet not substantially hamper crane capabilities in normal use. Therefore, this method is reasonable only in areas where mild sea conditions predominate, such as the Gulf of Mexico. A rating system of this type using a dynamic coefficient of 2.0 with zero offlead, 2% sidelead, and wind speed has been used in the Gulf of Mexico with good results for fixed platform cranes using tethered boat conditions.

B.4.3.1.a Vertical Design Coefficient C_v

Calculation of the dynamic coefficient C_v is based on a single DOF (degree of freedom) mathematical model. Although multiple DOF models have demonstrated enhanced ability to predict stresses in crane components, the single DOF model should adequately predict effects on the crane foundation. While stresses in the boom and other components are important for establishing service life, the primary safety concern lies in foundation stresses that may lead to a separation failure. Thus, a simple single DOF model has been chosen. The formula for C_v works for platform mounted cranes as well as floating cranes. The V_c term provides the motion of the crane boom tip to be combined with that caused by the supply boat (given by V_d). Since these two velocities occur randomly with respect to each other, they are combined by means of the square root of the sum of the squares.

The dynamic load on the crane is very much a function of the crane stiffness. The stiffer the crane; the larger the dynamic loading. The stiffness value K in Eq. 4.1 is meant to describe the amount of vertical displacement of the hook block that would occur for a given load application (lb/ft). It is calculated by accounting for the combined flexibility of the loadline, boomline, pendants, boom, and king post or pedestal. It should be calculated with the hook block at sea level where the supply boat lift will be made. The crane stiffness may vary considerably with radius.

Wire rope stiffness is typically the major contributor to crane flexibility. In the absence of wire rope manufacturer's information, the wire rope modulus of elasticity may be taken as 75,000 N/mm^2 (10.9 million psi) based on a cross-sectional area equal to 0.48 times the nominal rope diameter squared. This is reasonable for most Independent Wire Rope Core rope types commonly used for offshore cranes, but should not take the place of more accurate manufacturer's information.

Minimum Hoist Velocity. The minimum hoist velocity specified by Eq. 4.2 is intended to keep the load from re-contacting the supply vessel on the next wave crest. Table B.4.3.3 summarizes these velocities for various significant wave heights. This is the hoist velocity that should be available at water level where the supply boat lift is being made, accounting for number of layers of wire rope on the winch. Load charts should not be made for conditions where the available hoisting velocity is less than that calculated by Eq. 4.2 (unless agreed to by the purchaser).

Table B.4.3.3—Minimum Required Hook Speeds at the Supply Boat Deck vs. Significant Wave Height

H_{sig} (ft.)	V_{hmin} (ft/min.)	H_{sig} (m)	V_{hmin} (m/min.)
2.0 and less	31	0.6 and less	10
3.3	39	1.0	12
4.9	49	1.5	15
6.6	59	2.0	18
8.2	69	2.5	21
9.8	79	3.0	24
11.5	89	3.5	27
13.1	98	4.0	30
14.8	108	4.5	33
16.4	118	5.0	36
18.0	128	5.5	39
19.7	138	6.0	42
21.3	148	6.5	45
23.0	157	7.0	48

B.4.3.2.b Loads Due to Crane Vessel Inclinations and Crane Motions

The crane static inclination angles given in Table 4 represent reasonable operating limits for the various types of installations. In the past, some references have given static angles well past these and well past any reasonable operating condition. The intent was to strengthen the crane against unspecified dynamic loads by means of over-designing for the static inclinations. With the addition in this specification of reasonable crane vessel dynamic load specifications, the previous conservatism in static inclination angles is not required.

B.5.1 GENERAL

In applying the AISC Specification to cranes specifically, the design engineer is faced with making certain interpretations regarding functional differences of certain structural members on cranes compared to their counterpart in a building. This is particularly true in the case of the boom in regard to allowable compressive stresses, which AISC expresses in terms of the effective length factor (K) in regard to elastic buckling.

The numerical value of K is appropriately left to the design engineer, however, not without a sound engineering basis. For cranes with boom lines attached at the boom-tip, the factor for buckling in the vertical plane is $K = 1.0$ and for buckling out of the vertical plane the conservative assumption is $K = 2.0$ (for a "flagpole"). However, an assumed value of $K = 2.0$ for "out of plane" buckling can be overly conservative, especially for long booms. The correct effective length factor can be computed, but not in a simple or direct manner, as it is a function of resistance to sideload from the high-tension lines and this resistance increases with increasing load being lifted[21]. The procedure is generally implemented with the aid of a computer and, as a result, design curves are not readily available. Also required, in the computation of K for the overall boom, is the computation of an average moment of inertia required in arriving at a radius of gyration, for use in the AISC Specification. Methods for computing average moment of inertia of a laced column are available in the literature[22,23]. Effective length factors of individual boom components, i.e., unbraced portions of chords, and lacing members, must also be considered. Here again the design engineer can choose conservative values or he can perform buckling analyses (using finite element models) of the chord/lacing structural system. This type of analysis (finite element) is necessary to properly employ the AISC in the case of booms with lacing not meeting the requirements of Section E.4, which reads as follows:

"Lacing, including flat bars, angles, channels, or other shapes employed as lacing, shall be so spaced that the ratio l/r of the flange included between their connections shall not exceed $^3/_4$ times the governing ratio for the member as a whole. Lacing shall be proportioned to resist a shearing stress

[21]For example, see: Young, R. D., Pelletier, A. F., Metting, L. C., "The Mechanics of Crane Booms in Three Dimensions," presented at the Energy Technology Conference and Exhibition, 1978, Houston, Texas.
[22]*Guide for the Analysis of Guy and Stiffleg Derricks*, American Institute of Steel Construction, 1974.
[23]*Theory of Elastic Stability*; Timoshenko and Gere, 2nd Edition, McGraw-Hill, 1961.

normal to the axis of the member equal to 2% of the total compressive stress in the member. The ratio *l/r* for lacing bars arranged in single systems shall not exceed 140. For double lacing this ratio shall not exceed 200. Double lacing bars shall be joined at their intersections. For lacing bars in compression the unsupported length of the lacing bar shall be taken as the distance between fasteners or welds connecting it to the components of the built-up member for single lacing, and 70% of that distance for double lacing. The inclination of lacing bars to the axis of the member shall preferably be not less than 60° for single lacing and 45° for double lacing. When the distance between the lines of fasteners or welds in the flanges is more than 15 in., the lacing preferably shall be double or be made of angles."

Gantrys and A-frames should also be analyzed with regard to bending moments occurring at the braces. This is generally achieved with the use of finite element models.

B.5.4 FATIGUE

The 25,000 cycles of SWL × C_v design load, chosen as a minimum, is not to be construed as a representative number of loading cycles for offshore cranes, but rather as the lowest acceptable number of cycles to be used for design. Therefore, it remains the responsibility of each crane manufacturer to design their product in accordance with its expected usage, and of each crane purchaser to inform the manufacturer of any special requirements regarding duty cycle. However, the user should realize that designing for 25,000 cycles of SWL × C_v represents equivalent fatigue life for much higher numbers of cycles for loads less than SWL. Table B.5.4 shows equivalent fatigue lives calculated for the API X' curve with different assumed levels of load as a percent of SWL. For example, assuming C_v = 1.33, 25,000 cycles of 133% SWL cause the same fatigue damage as 970,000 cycles of 50% SWL.

Considering that all operational loads should be kept at or below SWL, the 25,000 cycle criteria should provide a reasonable level of fatigue design for most offshore cranes.

The treatment of hot spot stresses, as discussed in this specification, was adopted from API RP 2A[24]. Although that treatment was developed for tubular connections, the Specification 2C Task Group feels that it can be applied to offshore cranes as well, especially for non-typical connections which may exceed the scope of AISC Appendix B, and for welds which rely on length rather than cross-section, for the transfer of load.

B.6.1 DESIGN AUTHENTICATION

The manufacturer shall ensure that this design method does not change between models or cranes without re-performing design authentication testing. In that regard, it is recommended that the design procedure be well documented and complete. Many factors influence the strength of crane structures including material properties, weld strengths, lacing size and angle, and transition details in areas of stress concentrations. Any modification to a crane critical structural component should be documented by the manufacturer as meeting the standard design method or should be re-tested for design authentication.

Table B.5.4—Example Equivalent Fatigue Design Loads

Load, % of SWL	Equivalent Fatigue Cycles for X' Fatigue Curve
133	25,000
75	213,000
50	970,000
25	13,000,000

B.6.1.1 Resistance Type Strain Gauge Test

An example procedure for crane strain gauge testing is given in SAE J987[25] for cranes of Type C, D, or E from Figure 1 of this specification. An example procedure for cranes of Type A or B is given in SAE J1063[26]. These procedures discuss test measurements, gauge readings, procedures, and loading conditions typical for crane structures. They provide a good reference for typical crane test procedures.

B.6.1.2 Heavy Lift Load Test

The heavy lift test approach may not be appropriate for all cranes since stresses must be kept within the one-third increase in basic stress levels allowed by AISC. Also, the test must include detailed inspection of the crane critical components before and after completion of testing to determine if any components exhibited any yielding, buckling, indentations, or surface cracks.

B.7.2.4 Wire Rope—Design Factors

Wire rope is an expendable item and is routinely replaced in accordance with criteria set out in API RP 2D. It also has variable load-life characteristics that significantly differ from the more or less permanent components of the crane. Because of this and the many other inherent properties peculiar to wire rope, it was decided to set singular design factors taking into consideration each type rope and rope service. The design factors have been increased and, based on experience, are sufficiently large to account for minor strength effects such as specified sheave sizes, tackle dynamics and nominal vs. mini-

[24] API RP 2A-WSD *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design*, December 2000, Section 5, Figure 5.4-1—Fatigue S-N Curves.

[25] SAE J987 *Rope Supported Lattice-Type Boom Crane Structure—Method of Test*.

[26] SAE J1063 *Cantilevered Boom Crane Structures—Method of Test*.

mum rope strength. For that reason, the breaking strength of the boomlines and loadlines are divided by the total number of parts of line, not a reduced number accounting for reeving efficiency.

B.7.4.1 Minimum Sheave Ratios

The *D*/*d* ratio continues to use pitch diameter as opposed to root or tread diameter. The *D*/*d* ratio of 18 was chosen as sufficient for most offshore crane applications. Purchasers of cranes with heavier duty cycles or severe usage should consider the potential benefits of increasing the *D*/*d* ratio. Such an increase may result in longer rope life and reduced maintenance costs.

B.14 Material Requirements for Structural Components

Material requirements are specified herein to minimize failures of critical components whose fracture would result in loss of load or structural instability. It is intended that crane designers consider the significance of individual components and establish the criticality of each. These requirements are not intended to apply to components whose fracture would be considered a nuisance or inconvenience (e.g., band rails, cab enclosures, deck plating, etc.) but only components of the structural load transfer system. The properties and requirements for wire rope are detailed elsewhere and are not a part of these paragraphs.

B.14.1 MATERIALS

The vast majority of crane designs are based on well-founded engineering principles and manufacturing details are generally shown in detail on the resultant engineering drawings. Frequently, the material properties and strength requirements employed in the design considerations are lacking on the engineering drawings and are absent in documentation available to manufacturing personnel. The requirements of this paragraph are for the purpose of assuring consideration of the material properties to be used in critical components and the development of material specification based on those considerations.

B.14.2 TRACEABILITY

The traceability requirements minimize the inadvertent use of unintended or inappropriate materials for manufacture of critical components. Insistence upon traceability to the producers control parameter further minimizes errors in material usage resulting from clerical errors and unscrupulous certifications by third party material suppliers. When material traceability or identification is lacking, the crane manufacturer may elect to determine the properties of such materials by conducting tests within its own laboratories or in an outside facility. If the tests conducted by the crane manufacturer prove the materials of unknown origin conform to the manufacturer's design criteria, the test reports provide the documentation to justify use of the materials.

B.14.3 FRACTURE TOUGHNESS

Sudden or catastrophic failure of critical components is minimized by employing materials with sufficient fracture toughness to tolerate any inherent imperfections resulting from manufacturing or fabrication.

Indexing the Charpy impact energy requirements to the transition temperature provides a margin of safety against small flaw brittle fracture initiation at higher temperatures. For service exposures with frequent recurrence at or near the transition temperature, toughness requirements should be increased, the critical components protected from the low temperature exposure, or the design service temperature lowered to avoid frequent exposures to the transition temperature.

Brittle fracture occurs when the interdependent parameters of tensile stress, fracture toughness, and material imperfection exist in a critical combination. Of the three, fracture toughness is the parameter determined with greatest reliability. Determination of imperfection size by available nondestructive inspection techniques and assessment of actual stresses resulting from concentration factors and fabrication residuals is accomplished with less precision. Materials subjected to controlled thermal stress relief treatments are excluded from the small flaw fracture initiation category if the design considerations have accounted for stress concentration factors; i.e., the actual applied stresses are within commercial design codes.

Use of materials with brittle properties may be justified by designs that incorporate sufficient redundancy to assure continued safe operation of the machine should one or more of its members fail. Further justification for use of materials of uncontrolled fracture toughness can be provided by inspections and examinations to assure the materials are free of critical size imperfections and will remain free in subsequent service. For non-redundant components exposed to corrosive environments and cyclic stresses, design and manufacture of critical components using materials of known fracture resistance is the responsible engineering approach.

B.14.4 CASTINGS

Structural components of complex shape are more readily produced by casting the part to final shape rather than machining from wrought shapes or by forging to the approximate final form. Sound steel castings exhibit properties comparable to their wrought counterpart. The soundness of castings depends, largely, on the foundry practice, particularly the initial procedures to feed the flask with hot metal. The validity of the pouring procedure is verified either by destructive sectioning of a prototype casting to reveal potential shrinkage, porosity, sand and dross entrapment, etc., or by nondestructive examinations capable of disclosure and definition of imperfections in all critical areas of the casting. Radiography is the traditional technique for this purpose and graded standards of acceptance have been developed by the American Society for Testing Materials for use in selecting the quality level compatible with the design criteria.

Prototype examinations indicate sound casting practices are not an assurance all castings produced by the procedure will exhibit equal quality; therefore, the prototype procedures should be developed to assure acceptable soundness under routine foundry practice. The acceptance criteria specified in Table 10 is for that purpose. Specification of these quality levels does not result in delivery of castings free of all imperfections, nor does it impose requirements beyond the capabilities of commercial foundries. The crane designer is encouraged to become thoroughly familiar with the imperfections permitted by these requirements and assess the significance on the individual design reliability.

Resistance of castings to brittle fracture is improved by the absence of residual solidification and cooling stresses. Controlled cooling of castings following the solidification results in significant reductions in residual stresses; however, castings removed from the mold at temperatures above the steel's transformation temperature and cooled rapidly to enhance strength properties can result in significant residual stress levels. Shakeout procedures for control of properties and residual stresses are often poorly controlled at the foundry necessitating a subsequent thermal treatment under controlled conditions.

B.14.5 FASTENERS

Fasteners subjected to high tensile and/or dynamic loading are potential brittle fracture candidates due to inherent notch effects of thread geometry. Crane designers should assess the criticality of all bolted connections and consider the advantages of specifying round-bottom or rolled-thread profiles.

Fasteners of critical classification are required herein to possess a minimum strength level and adequate fracture toughness to minimize fracture initiating at fatigue cracks resulting from cyclic loading and/or corrosion pitting from exposure to the marine environment. When fasteners of higher strength than attainable from the specification of ASTM A 320/A 320M are employed, selections shall be justified by design considerations and testing to assure compliance with the design requirements.

For service design temperatures approaching or below zero degrees Fahrenheit (minus 17.8°C), the crane designer should consider more stringent fracture toughness requirements as compensation for the thread stress concentration factors and the inherent propensity for brittle fracture in high strength steels.

For all critical fasteners, the designer should consider the provisions of Section 9.2.4 imposed on swing-circle fasteners and develop assembly specifications to assure proper installation and makeup of the fastener.

B.14.6 PLATE

Lamellar tearing of rolled plate was first documented as a failure mechanism shortly after the development of arc welding as a fabrication tool. The potential for failure by lamellar tearing became more widely recognized following several instances of failure in North Sea structures.

Research by British investigators related the mechanism of lamellar tear to nonmetallic inclusions retained from the steel making process. Laboratory investigations and mill test procedures were correlated to define a mechanical property that could be employed as an acceptance tool for procurement of plate resistant to lamellar tearing. The tool was found in a simple tensile test conducted on specimens removed from the through thickness direction of the plate.

Steel makers have developed methods of reducing the density, size and shape of residual nonmetallic inclusions which permits loading of the plate in the through thickness direction without significant hazards of lamellar tearing.

Specification of the through thickness tensile test requirement on procurement of plate together with ultrasonic examinations provide assurance that the material has a low level of nonmetallic inclusions as well as freedom from large laminations resulting from ingestion of other contaminants or from rolling practice.

Crane design engineers should evaluate all design details which result in loading in the through thickness direction and either modify the detail to eliminate through thickness loading or prepare a procurement specification employing the additional performance requirements detailed in this paragraph.

B.15 Welding of Critically Stressed Components

The performance of critical welded components of the crane is contingent upon welding procedures that develop the strength and fracture toughness of the materials joined by the welding. The ability of the welders to apply the provisions of the procedures is assured by examination and performance tests outlined by the referenced welding standards organizations.

B.15.2 WELDING PROCEDURES

Written welding procedures are essential to control of critical member fabrications. Procedures should be in sufficient detail and clarity to be readily interpreted by shop fabrication personnel. The prequalified procedures described in the American Welding Society specifications are reliable for joining steels of known weldability and those listed in the specifications. These procedures will generally yield acceptable results on the tabulated materials and need not be proven by actual laboratory testing. The performance of these procedures for welding alloy steels and others unlisted in the specifications is uncertain. For these steels, laboratory testing is specified to assure the procedures employed will yield satisfactory results.

B.15.3 WELDER PERFORMANCE

The manipulative skills of welders can be ascertained by radiography or by destructive bend testing when welding processes are employed with known characteristics devoid of a propensity to produce fusion and other planar type defects. When welders are to be qualified on short-circuiting (short-arc) gas metal arc welding, destructive bend testing is employed to detect the presence of planar imperfections which may be inherent in the use of the process.

B.15.4 WELDING PROPERTIES

The American Welding Society specifications provide minimum guidance for assessment of procedures for welding fracture-controlled materials. When developing procedures for the joining of fracture resistant materials, the requirements of the American Society of Mechanical Engineers should be employed with fracture toughness testing imposed on the weld and heat-affected zones. Charpy impact testing is the traditional sampling technique; however, the crane manufacturer utilizing a fitness-for-purpose design philosophy may wish to substitute crack opening displacement or plane strain fracture toughness testing for the Charpy tests.

B.16 Nondestructive Examination of Critical Components

Nondestructive examinations provide some added assurance that critically stressed components and fabrications are free of imperfections capable of initiating fractures. The extent of examination and the imperfection acceptance limit are considerations dependent on material properties, design stress levels, structural redundancy, and criticality of the component. These considerations are an integral part of the design process, and form the basis on which control personnel develop the operating procedures for inspections and examinations to be conducted during the course of manufacturing and fabrication.

B.16.1 NONDESTRUCTIVE EXAMINATION PROCEDURES

The applicability of method and extent of inspection are essential factors in the validity of any nondestructive examination program. Radiographic examinations are effective in the detection of internal three-dimensional imperfections in castings and butt welds. The method is less effective in the detection of planar imperfections such as cracks and lack of fusion or in the examination of tee butt configurations, which limit optimum orientation of the radiation beam and film placements. Ultrasonic examination techniques yield more reliable results in the detection of planar imperfections provided the procedure employed results in a perpendicular interception of the sound beam and imperfection. Magnetic particle examinations are equally sensitive to the orientation of the magnetic field with respect to the imperfection orientation and for practical purposes can be relied upon only for detection of surface or near surface defects. The reliability of liquid penetrant techniques, also limited to surface defect detection, is influenced strongly by surface contaminants such as oil and grease. Inadequate cleaning, insufficient penetrant dwell time, poor excess penetrant removal, and improper developing techniques all influence the reliability of the technique.

These factors should be considered by the crane manufacturer's engineering and quality control personnel in the development of non-destructive examination procedures to obtain the optimum results possible from the attributes of each available method. The procedures and specification requirements of the ASME *Boiler and Pressure Vessel Code, Section V—Nondestructive Examination* provide an excellent source of information for development of working nondestructive examination procedures.

Conducting the examinations immediately following processing which can introduce new material imperfections eliminates potential entry of imperfect materials into the manufacturing system and minimizes waste of available manpower expended on work later to be discarded.

B.16.2 NONDESTRUCTIVE EXAMINATION PERSONNEL QUALIFICATIONS

Present commercial practice for nondestructive examination personnel competency verification places responsibility for the verification on the manufacturer. The commercial practice is contained in a recommended practice published by the American Society of Nondestructive Testing, which details requirements for personnel education, training, and certification. In addition to verification of captive employees, these recommendations are equally applicable to personnel employed on a contract basis. Regardless, the manufacturer retains responsibility for the contractor's competency.

The unique features of tubular member truss structures require the use of corrections and procedures not common in the ultrasonic examination of plate and rolled shape welding. The American Petroleum Institute recognized these added requirements and developed a recommended practice to qualify personnel using these techniques. When the ultrasonic technique is used for this purpose, the API recommendations for personnel verification are appropriate.

B.16.3 MINIMUM EXTENT OF NONDESTRUCTIVE EXAMINATION

When nondestructive examinations are based on fitness-for-purpose design philosophies, the choice of examination methods and acceptance criteria are functions of materials properties, magnitude and direction of stress, and the anticipated accuracy in flaw size measurement. These factors are to be determined by documented testing of materials and appropriate calculations of acceptable flaw sizes based on recognized fracture mechanics methodology.

B.16.4 EXAMPLES OF WORKMANSHIP STANDARDS

Section 16.4 illustrates some components of cranes, which may be considered critical in some designs, together with applicable methods of examinations and appropriate acceptance criteria. Each crane manufacturer should assess its designs for application of these examinations. Consideration of load applications (tension, shear, compression) is pertinent to the decision to use these examinations and acceptance criteria. The basis of the decisions should be documented and available for review by the purchaser.

APPENDIX C—MINIMUM PURCHASER-DEFINED REQUIREMENTS

Installation Description:

Type of Installation: ______________________ (Fixed Platform, TLP, Spar, Semi, Drillship)

Installation Main Deck Elevation above Sea Level: ________ ft

Crane Boom Heel Pin Elevation above Main Deck: ________ ft

Minimum Design Service Temperature: ____________ °F

Maximum Design Service Temperature: ____________ °F

Features:

Boom Length: _____ ft

Primer Mover: ______________________

Area Classification: (See Section 10.4)

At Crane:	Class ________	Division ________	Group(s) ________
Boom:	Class ________	Division ________	Group(s) ________
Power Unit:	Class ________	Division ________	Group(s) ________

Out-of-service Maximum Conditions:

Boom Not Stowed:

Max Wind ____ mph

For Floating Crane Vessel/Platforms:

Max Significant Sea (H_{sig}) ______ ft

Max Crane Accelerations:

____ Per Tables 3 – 5 for specified H_{sig}

____ g's horiz. and ____ g's vert.

Boom Stowed:

Max Wind ____ mph

For Floating Crane Vessel/Platforms:

Max Significant Sea (H_{sig}) ______ ft

Max Crane Accelerations:

____ Per Tables 3 – 5 for specified H_{sig}

____ g's horiz. and ____ g's vert.

Performance Requirements:

Ratings to be determined by which method (check one):

☐ Vessel Specific Method (Floating Crane Vessels only)

☐ General Method (Floating or Fixed Crane Installations)

☐ Default Dynamic Method (Fixed Platforms only—calm seas, tethered supply boat)

Minimum Purchaser Defined Criteria for Fixed or Floating Installations

Purchaser Defined Lift Criteria	Onboard Lifts (Calm Seas)	Onboard Lifts 2nd Criteria	Offboard Lifts 1st Criteria	Offboard Lifts 2nd Criteria
Main Block Required SWL—lb.				
Main Block SWL Radius—ft				
Auxiliary Required SWL—lb.				
Auxiliary Hook SWL Radius—ft				

Additional Criteria for Fixed/Bottom Supported or Floating/Vessel Installations

Purchaser Defined Lift Criteria	Onboard Lifts (Calm Seas)	Onboard Lifts 2nd Criteria	Offboard Lifts 1st Criteria	Offboard Lifts 2nd Criteria
Main Block Speed @ Supply Boat Deck—ft/sec.	n/a			
Auxiliary Hook Speed @ Supply Boat Deck—ft/sec.	n/a			
Significant Wave Height (H_{sig})—ft	n/a			
Wind Speed—mph				

Additional Purchaser Defined Criteria—Floating/Vessel Installation Cranes Only (TLP/Spar/Semisubmersible/Drillship/Etc.)

Purchaser Defined Lift Criteria	Onboard Lifts (Calm Seas)	Onboard Lifts 2nd Criteria	Offboard Lifts 1st Criteria	Offboard Lifts 2nd Criteria
Crane Base Static Inclination, (Installation List Angle)—degrees				
Crane Base Static Inclination, (Installation Trim Angle)—degrees				
Boom Tip Velocity—ft/sec.	n/a			
Horizontal Acceleration—g's	n/a			

$1g = 32.2$ ft/sec.^{2}

APPENDIX D—API MONOGRAM MARKING

Manufacturers holding a Monogram License from API may apply the API Monogram to the nameplate as a warranty to the purchaser that construction of the crane complies in all details to API Spec 2C, and was manufactured under a quality control system which conforms to API Spec Q1. When applied to the nameplate, the API Monogram (including the manufacturer's license number) shall not be less than 1/2 in. high and shall appear in the position shown in Figure D.1. The required information shall be imprinted in legible raised or stamped lettering not less than 1/8 in. (4 mm) high.

Manufacturers interested in obtaining an API Monogram License should contact the American Petroleum Institute by writing to API Quality Programs, 1220 L St., N.W., Washington, D.C. 20005 (telephone 202-682-8000) for an application package or contact API by email at quality@api.org.

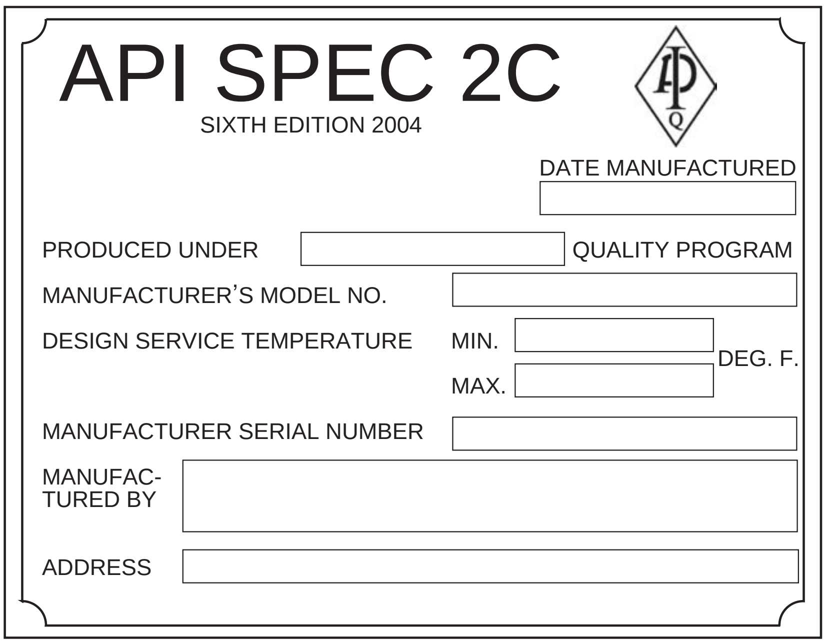


Figure D.1—API Monogram Nameplate

APPENDIX E—EXAMPLE CALCULATIONS

E.1 CALCULATION OF CRANE DESIGN LOADS FOR A TYPICAL LOAD CONDITION

A crane is lifting a SWL of 20000 lb. at a radius of 100 ft from a supply boat. The lift is being made in a 6.6 ft significant sea (2 m) from a drillship. Using the General Method (no vessel specific motions supplied), calculate the design loads acting on the crane. For this simplified example, no wind loads will be considered.

Crane Details: Max hoist speed on the load line hoist is 200 ft/min. and the crane is rigged with 2 part loadline. Stiffness of the crane was calculated as 24000 lb/ft. The crane boom length is 140 ft. At the 100 ft radius, the crane boom angle is 47° from horizontal. The boom heel pin is 30 ft above the main deck which is 70 ft above sea level. The lift is being made with the crane pointed directly off the port side of the drillship.

Vertical Design Load: To determine the vertical design load, C_v must be calculated for offboard lifts per Eq. 4.1.

$$C_v = 1 + V_r \times \sqrt{\frac{K}{g \times \mathrm{SWL}}} \text{ but not less than 1.33} \qquad \text{(Eq. 4.1)}$$

where

K = vertical spring rate of the crane at the hook, lb/ft,

SWL = Safe Working Load or rated load, lb.,

g = acceleration due to gravity, 32.2 ft/sec.^{2},

$V_r = V_h + \sqrt{V_d^2 + V_c^2}$ = relative velocity, ft/sec.,

V_h = maximum actual steady hoisting velocity for the SWL to be lifted, ft/sec.,

V_d = vertical velocity of the supply boat deck supporting the load, ft/sec.,

V_c = vertical velocity of the crane boom tip due to crane base motion, ft/sec.

To calculate C_v, we must know the significant wave height H_{sig} (6.6 ft), the crane stiffness K (given above as 24000 lb/ft), the SWL (20000 lb.), V_h, V_d, and V_c. The max hoist velocity V_h = 200 ft/min. divided by 2 line parts = 100 ft/min. The supply boat deck velocity $V_d = 0.6 \times 6.6 = 3.96$ ft/sec. from Table 2 equation. $V_c = .05 \times H_{sig} \times H_{sig}$ per Table 2, or $V_c = 0.05 \times 6.6 \times 6.6 = 2.18$ ft/sec. The combined $V_r = V_h + (V_d^2 + V_c^2)^{1/2} = 6.19$ ft/sec. = 371.4 ft/min. So $C_v = 1 + 6.19 \times (24000/(32.2 \times 20000))^{1/2} = 2.195$ per Eq. 4.1. The Vertical Design Load to be used in the crane strength calculations = SWL $\times C_v = 20000 \times 2.195 = 43900$ lb. For normal rating calculations, the crane manufacturer would have to iterate on C_v. The procedure would be to determine the minimum allowable design load for the controlling component, and then use Eq. 4.1 to iterate and determine the allowable SWL. For this simplified example, determination of a limiting design load and the C_v iteration were not performed.

Minimum Hook Speed: The API minimum hook speed required for the 6.6 ft seastate is 0.99 ft/sec. or 59.4 ft/min. per Eq. 4.2. The actual max hook speed of 100 ft/min. exceeds this as required. The max actual hook speed must be used in Eq. 4.1 to calculate C_v.

Offlead and Sidelead Due to Supply Boat Motion: Per Eq. 4.3, the offlead force is:

$$W_{\mathrm{offSB}} = \mathrm{SWL} \times C_v \times \frac{2.5 + 0.457 \times H_{\mathrm{sig}}}{0.305 \times (H_w + \mathrm{BL} \times \sin(\phi))} \text{ lb.} \qquad \text{(Eq. 4.3)}$$

where

H_w = vertical distance from boom heel pin to supply boat deck, ft,

SWL = Safe Working Load, lb.,

BL = boom length, ft,

ϕ = boom angle to horizontal.

From the crane information given above, SWL = 20000 lb., C_v = 2.195, BL = 140 ft, H_w = 70 + 30 = 100 ft, and ϕ = 47°. W_{offSB} = SWL × C_v × 0.0894 = 3923 lb.

The horizontal sideload applied at the boom tip due to supply boat motion shall be:

$$W_{sideSB} = W_{offSB}/2 \text{ lb.} \quad \text{(Eq. 4.4)}$$

However, W_{sideSB} shall not be less than 0.02 × SWL × C_v.

$$W_{sideSB} = \text{SWL} \times C_v \times (0.0894/2) = \text{SWL} \times C_v \times 0.0447 > 0.02 \times \text{SWL} \times C_v$$

$$W_{sideSB} = 1961 \text{ lb.}$$

Horizontal Loads Due to Static Crane Inclinations: Per Table 4 for a drillship, the static inclinations shall be 2.5° heel and 1° trim for the General Method. Since the crane boom is pointing in the port direction (as described above), the 2.5° heel will cause offlead and the 1° trim will cause sidelead. The offlead will be accounted for by the operator adjusting his boom angle to get back to the 100 ft radius prior to making the lift. The sidelead will be as given by Eq. 4.5:

$$W_{sideCI} = \text{SWL} \times C_v \times \tan(\text{StaticSideLeadAngle}) \text{ lb.} \quad \text{(Eq. 4.5)}$$

Or W_{sideCI} = SWL × C_v × tan(1°) = 20000 × 2.195 × (0.01746) = 766 lb. The 1° trim angle will also cause similar side loads due to the boom and other crane components equal to their weight times tan(1°). These side loads should be applied to the boom and other crane components at their c.g's.

Horizontal Loads Due to Crane Motions: Per Table 4 for a drillship, the horizontal acceleration in g's = 0.01 × $(H_{sig})^{1.1}$ but not less than 0.03. For H_{sig} = 6.6 ft, the horizontal acceleration = 0.08 g's. This acceleration should be applied as either a side acceleration on the crane or an offlead acceleration on the crane, whichever creates the worst condition for the controlling component. For this example, let's assume that the crane is oriented such that this load causes offlead (since the boom is pointed in the port direction, this means we are assuming the crane horizontal accelerations are occurring in the port to starboard direction as well or CraneBaseAngle = 0°). From Eq. 4.6 through 4.8:

$$W_{horizontalCM} = \text{SWL} \times C_v \times \text{HorizontalAcceleration} \text{ lb.} \quad \text{(Eq. 4.6)}$$

Or:

$$W_{horizontalCM} = 20000 \times 2.195 \times 0.08 = 3512 \text{ lb.}$$

And:

$$W_{offCM} = W_{horizontalCM} \times \cos(\text{CraneBaseAngle}) \text{ lb.} \quad \text{(Eq. 4.7)}$$

$$W_{sideCM} = W_{horizontalCM} \times \sin(\text{CraneBaseAngle}) \text{ lb.} \quad \text{(Eq. 4.8)}$$

where

CraneBaseAngle = assumed angle of crane base motions from direction of boom (0° for only offlead, 90° for only sidelead).

For this example,

$$W_{\text{horizontalCM}} = 20000 \times 2.195 \times 0.08 = 3512 \text{ lb.}$$

$$W_{\text{offCM}} = 3512 \text{ lb.}$$

$$W_{\text{sideCM}} = 0 \text{ lb.}$$

Similar horizontal forces result from the boom and other crane components due to crane vessel horizontal accelerations. These added horizontal loads shall be calculated for the various crane components and applied to the various crane components at their c.g's.

Combination of Horizontal Design Loads: The combined horizontal loads for this example due to the SWL per Eq. 4.9 through 4.12 are:

Sidelead force W_{sidedyn}:

$$W_{\text{sidedyn}} = \sqrt{\{W_{\text{sideSB}}\}^2 + \{W_{\text{sideCM}}\}^2} \text{ lb.} \quad \text{(Eq. 4.9)}$$

Offlead force W_{offdyn}:

$$W_{\text{offdyn}} = \sqrt{\{W_{\text{offSB}}\}^2 + \{W_{\text{offCM}}\}^2} \text{ lb.} \quad \text{(Eq. 4.10)}$$

This combined dynamic horizontal load is then added to horizontal loads due to static crane base inclinations and winds to arrive at the total horizontal design force to be considered for the specified crane rating conditions as:

$$\text{Total Offload} = W_{\text{offdyn}} + W_{\text{off(FromWind)}} \text{ lb.} \quad \text{(Eq. 4.11)}$$

$$\text{Total Sideload} = W_{\text{sidedyn}} + W_{\text{sideCI}} + W_{\text{side(FromWind)}} \text{ lb.} \quad \text{(Eq. 4.12)}$$

Or for this example:

$$W_{\text{sidedyn}} = (1961 \times 1961 + 0 \times 0)^{\frac{1}{2}} = 1961 \text{ lb.}$$

$$W_{\text{offdyn}} = (3923 \times 3923 + 3512 \times 3512)^{\frac{1}{2}} = 5265 \text{ lb.}$$

And:

$$\text{Total Offload} = 5265 + 0 = 5265 \text{ lb.}$$

$$\text{Total Sideload} = 1961 + 766 + 0 = 2727 \text{ lb.}$$

Loads Due to Boom Weight. The vertical loads due to boom weight are increased by the value in Table 5 to account for crane motions on floating crane platforms. For the 6.6' H_{sig} on a drillship, the actual weight of the boom is increased by a multiplier equal to $1.0 + 0.0012 \times H_{sig} \times H_{sig} \geq 1.07$. For $H_{sig} = 6.6$, this multiplier equals 1.07 because the formula gives 1.052 which is smaller than the minimum 1.07 specified. The boom weights (as well as the other crane components) should be increased by this multiplier in the crane rating calculations.

The horizontal loads due to the boom are determined by applying Eq. 4.5 through 4.8 (see Section 4.3.2.b) to the boom weight instead of SWL × C_v. For this example,:

$$\text{Boom}_{\text{sideCI}} = \text{BoomWeight} \times \tan(1°) = \text{BoomWeight} \times (0.01746) \qquad \text{(Eq. 4.5)}$$

$$\text{Boom}_{\text{horizontalCM}} = \text{BoomWeight} \times \text{HorizontalAcceleration} \qquad \text{(Eq. 4.6)}$$

Or:

$$\text{Boom}_{\text{horizontalCM}} = \text{BoomWeight} \times 0.08$$

And:

$$\text{Boom}_{\text{offCM}} = \text{Boom}_{\text{horizontalCM}} \times \cos(\text{CraneBaseAngle}) \qquad \text{(Eq. 4.7)}$$

$$\text{Boom}_{\text{sideCM}} = \text{Boom}_{\text{horizontalCM}} \times \sin(\text{CraneBaseAngle}) \qquad \text{(Eq. 4.8)}$$

In addition to the above loads, the vertical and horizontal loads must be computed due to the same effects acting on the other crane components and these loads applied at the component c.g.'s.

E.2 CALCULATION OF OVERTURNING MOMENT AND OTHER LOADS AT PLATFORM/ CRANE INTERFACE

The overturning moments, axial load, and radial load acting at the platform/pedestal interface shall be calculated for the example given in E.1. These loads will include the additional 1.5 design factor required by Section 5.2.

Additional Crane Details: In addition to the information given in E.1, the following information is provided. The 140' boom weighs 25,000 lb. and the c.g. of the boom is 80 ft from the heel pin. The heel pin is mounted 4.5 ft horizontally from the center of the pedestal (center of rotation). The crane c.g. (without the boom) is 2 ft behind the center of rotation (opposite the boom direction) and 7 ft above the boom heel pin. The crane weighs 100000 lb. without the boom. Again, wind loads are neglected for this simplified example.

Due to Vertical Design Load: The loads due to the vertical design load (including the 1.5 factor of Section 5.2) are:

$$\text{Vertical Load} = \text{SWL} \times C_v \times 1.5 = 20000 \times 2.195 \times 1.5 = 65850 \text{ lbs}$$

$$\text{Inplane Moment} = \text{Axial Load} \times \text{Radius} = 65850 \times 100 = 6585000 \text{ ft-lb.}$$

Due to SWL Offload: The total offload resulting from the presence of the SWL was given in Eq. 4.11. For this example it was 5265 lb.

$$\text{Offload} = (\text{Eq. 4.11 Total Offload}) \times 1.5 = 5265 \times 1.5 = 7897 \text{ lb.}$$

$$\text{Inplane Moment} = (\text{Offload} \times \text{Boom Tip Height above Pedestal Base}) = 7897 \times (30 + 140 \times \sin(47°))$$

$$= 7897 \times 132.4 = 1045563 \text{ ft-lb.}$$

Due to SWL Sideload: The total sideload resulting from the presence of the SWL was given in Eq. 4.12. For this example it was 2727 lb.

$$\text{Sideload} = (\text{Eq. 4.12 Total Sideload}) \times 1.5 = 2727 \times 1.5 = 4090 \text{ lb.}$$

$$\text{Sideplane Moment} = \text{Sideload} \times (\text{Boom Tip Height above Pedestal Base}) = 4090 \times 132.4 = 541516 \text{ ft-lb.}$$

$$\text{Torque} = \text{Sideload} \times \text{Radius} = 4090 \times 100 = 409000 \text{ ft-lb.}$$

Due to Boom Weight: The loads due to boom weight (and other crane components) are not subject to the 1.5 factor in Section 5.2. Crane and boom weights result in vertical, offload, and sideloads due to floating crane motions (and wind). For this example, these are:

$$\text{Boom Vertical Load} = \text{Boom Weight} \times \text{Table 5 Factor} = 25000 \times 1.07 = 26750 \text{ lb.}$$

$$\text{Boom Offload} = \text{Boom Weight} \times \text{Offlead Horizontal Acceleration (see Eq. 4.6 - 4.8)} = 25000 \times 0.08 = 2000 \text{ lb.}$$

$$\text{Inplane Moment} = \text{Vertical Boom Load} \times (\text{Horiz. Distance from Pedestal Center to Boom C.G.}) +$$

$$\text{Boom Offload} \times (\text{Boom C.G. Height above Pedestal Base}) + \text{Wind Effects} = 26750 \times (80 \times \cos(47°) + 4.5) + 2000$$

$$\times (30 + 80 \times \sin(47°)) = 1756868 \text{ ft-lb.}$$

$$\text{Boom Sideload} = \text{Boom Weight} \times [\tan(\text{Static Sidelead Angle}) + \text{Sidelead Horizontal Acceleration}] + \text{Wind Effects}$$

$$= 25000 \times \tan(1°) + 0 + 0 = 437 \text{ lb.}$$

$$\text{Sideplane Moment} = \text{Boom Sideload} \times (\text{Boom C.G. Height above Pedestal Base}) + \text{Wind Effects}$$

$$= 437 \times (30 + 80 \times \sin(47°)) = 38678 \text{ ft-lb.}$$

$$\text{Torque} = \text{Boom Sideload} \times (\text{Horiz. Distance from Pedestal Center to Boom C.G.})$$

$$= 437 \times (80 \times \cos(47°) + 4.5) = 25809 \text{ ft-lb.}$$

Due to Crane Weight (other than boom): The loads due to crane weight are not subject to the 1.5 factor in Section 5.2. Crane weights result in vertical, offload, and sideloads due to floating crane motions (and wind). For this example, these are:

$$\text{Crane Vertical Load} = \text{Crane Weight} \times \text{Table 5 Factor} = 100000 \times 1.07 = 107000 \text{ lb.}$$

$$\text{Crane Offload} = \text{Crane Weight} \times \text{Offlead Horizontal Acceleration (see Eq. 4.6 - 4.8)} = 100000 \times 0.08 = 8000 \text{ lb.}$$

$$\text{Implane Moment} = \text{Vertical Crane Load} \times (\text{Horiz. Distance from Pedestal Center to C.G.}) + \text{Crane Offload}$$

$$\times (\text{C.G. Height above Pedestal Base}) + \text{Wind Effects} = 107000 \times (-2) + 8000 \times (30 + 7) = 82000 \text{ ft-lb.}$$

$$\text{Crane Sideload} = \text{Crane Weight} \times [\tan(\text{Static Sidelead Angle}) + \text{Sidelead Horizontal Acceleration}] + \text{Wind Effects}$$

$$= 10000 \times [\tan(1°) + 0] + 0 = 1746 \text{ lb.}$$

$$\text{Sideplane Moment} = \text{Crane Sideload} \times (\text{C.G. Height above Pedestal Base}) + \text{Wind Effects} = 1746 \times (30 + 7)$$

$$= 64602 \text{ ft-lb.}$$

$$\text{Torque} = \text{Crane Sideload} \times (\text{Horiz. Distance from Pedestal Center to C.G.}) = 1746 \times (-2) = -3492 \text{ ft-lb.}$$

For this example:

Total Axial Load = 65850 + 26750 + 107000 = 199600 lb.

Total Offload = 7897 + 2000 + 8000 = 17897 lb.

Total Sideload = 4090 + 437 + 1746 = 6273 lb.

Total Inplane Moment = 6585000 + 1045563 + 1756868 + 82000 = 9469431 ft-lb.

Total Sideplane Moment = 541516 + 38678 + 64602 = 644796 ft-lb.

Total Torque = 409000 + 25809 + (–3492) = 431317 ft-lb.

The inplane and sideplane components can be combined by square root of the sum of the squares to yield combined maximum loads of:

Total Axial Load = 199600 lb.

Total Radial Load = 18965 lb.

Total Overturning Moment = 9491358 ft-lb.

Total Torque = 431317 ft-lb.

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