ASME NOG-1–2015
(Revision of ASME NOG-1–2010)

# Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)



AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

INTENTIONALLY LEFT BLANK

ASME NOG-1–2015
(Revision of ASME NOG-1–2010)

# Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)



AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers
Two Park Avenue • New York, NY • 10016 USA

Date of Issuance: February 20, 2015

The next edition of this Standard is scheduled for publication in 2020.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. Interpretations are published on the ASME Web site under the Committee Pages at http://cstools.asme.org/ as they are issued.

Errata to codes and standards may be posted on the ASME Web site under the Committee Pages to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in codes and standards. Such errata shall be used on the date posted.

The Committee Pages can be found at http://cstools.asme.org/. There is an option available to automatically receive an e-mail notification when errata are posted to a particular code or standard. This option can be found on the appropriate Committee Page after selecting "Errata" in the "Publication Information" section.





This code or standard was developed under procedures accredited as meeting the criteria for American National Standards. The Standards Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

ASME does not "approve," "rate," or "endorse" any item, construction, proprietary device, or activity.

ASME does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to insure anyone utilizing a standard against liability for infringement of any applicable letters patent, nor assumes any such liability. Users of a code or standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representative(s) or person(s) affiliated with industry is not to be interpreted as government or industry endorsement of this code or standard.

ASME accepts responsibility for only those interpretations of this document issued in accordance with the established ASME procedures and policies, which precludes the issuance of interpretations by individuals.



The American Society of Mechanical Engineers
Two Park Avenue, New York, NY 10016-5990

# CONTENTS

**Figures**



**Tables**

**Mandatory Appendices**



**Nonmandatory Appendices**

# FOREWORD

The Committee on Cranes for Nuclear Power Plants was first established in 1976. In 1980, the name and scope of the Committee were revised from the Committee on Cranes for Nuclear Power Plants to the Committee on Cranes for Nuclear Facilities. This Standard was developed under procedures accredited as meeting the criteria for American National Standards. The Standards committee that approved the Standard was balanced to ensure that individuals from competent and concerned interests have had an opportunity to participate.

This Standard or portions thereof can be applied to cranes at facilities other than nuclear, where enhanced crane safety may be required, and can be provided by means of either single-failure-proof features or a seismic design.

Suggestions for improvement as gained in the use of this Standard are welcome. They should be sent to the Secretary, ASME Committee on Cranes for Nuclear Facilities, The American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

The first edition of NOG-1 was approved in 1983, the second in 1989, the third in 1995, the fourth in 1998, the fifth in 2002, and the sixth in 2004. This 2014 edition contains the revisions made since the 2010 edition; most significant of these is the addition of Mandatory Appendix II on criteria required for structural qualification of an existing crane bridge for use with an ASME NOG-1 Type I hoist and trolley. Mandatory Appendix II parallels the U.S. Nuclear Regulatory Commission's guidance for modification of existing cranes for compliance with NUREG-0554, as presented in NUREG-0612 Nonmandatory Appendix C. ASME NOG-1–2015 received ANSI approval on January 8, 2015.

# ASME COMMITTEE ON CRANES FOR NUCLEAR FACILITIES

(The following is the roster of the Committee at the time of approval of this Standard.)

## STANDARDS COMMITTEE OFFICERS

**A. S. Kureck,** *Chair*
**S. Parkhurst,** *Vice Chair*
**G. M. Ray,** *Vice Chair*
**L. Powers,** *Secretary*

## STANDARDS COMMITTEE PERSONNEL

**B. K. Barber,** Navy Crane Center
**S. W. Butler,** Kennecott Utah Copper
**T. Finnegan,** Lockheed Martin Space Systems
**A. Reisner,** *Alternate,* Lockheed Martin Space Systems
**M. B. Fitzsimmons,** Constellation Energy Group
**J. N. Fowler,** DP Engineering Ltd. Co.
**L. C. Fraser,** Newport News Shipbuilding
**W. A. Horwath,** Whiting Corp.
**D. Weber,** *Alternate,* Whiting Corp.
**S. Huffard,** URS Corp.
**S. R. Jones,** U.S. Nuclear Regulatory Commission
**J. Knight,** Bechtel Marine Propulsion Corp.
**J. Konop,** PaR Systems
**J. B. Kriner,** Beckman & Associates
**A. S. Kureck,** Magnetek Material Handling
**J. A. Wellnitz,** *Alternate,* Magnetek Material Handling
**C. Larouche,** COH, Inc.
**S. M. Lawrence,** Konecranes Nuclear Equipment & Services, LLC
**J. D. Edmundson,** *Alternate,* Konecranes Nuclear Equipment & Services, LLC
**R. C. Lindberg,** Sargent & Lundy, LLC
**B. P. Lytle,** NASA Kennedy Space Center
**S. Parkhurst,** Material Handling Equipment, Inc.
**D. L. Borska,** *Alternate,* Material Handling Equipment, Inc.
**R. J. Parler,** AREVA
**L. Powers,** The American Society of Mechanical Engineers
**G. M. Ray,** Tennessee Valley Authority
**B. B. Bacon,** *Alternate,* Tennessee Valley Authority
**J. Schulz,** Westinghouse
**S. Henderson,** *Alternate,* Westinghouse
**N. E. Skogland,** Eureka Engineering, LLC
**G. A. Townes,** Be, Inc.
**T. V. Vine,** GDF Suez
**J. L. Weamer,** Bechtel National, Inc.
**T. A. Wetzel,** American Crane and Equipment Corp.

## SUBCOMMITTEE ON OPERATION AND MAINTENANCE FOR CRANES

**G. M. Ray,** *Chair,* Tennessee Valley Authority
**L. S. Gibbs,** Southern Nuclear
**R. D. Hagler,** Pacific Gas & Electric Co.
**D. E. Klasel,** Ace World Companies
**S. McArdle,** NEIL
**C. A. White,** U.S. Department of Energy

## SUBCOMMITTEE ON ENGINEERING SUPPORT

**D. Weber,** *Chair,* Whiting Corp.
**K. Axelson,** Zion
**J. Griesemer,** American Crane & Equipment Corp.
**L. D. Jones,** NASA Kennedy Space Center
**H. Pratt,** Crane Powerline Safety Organization
**S. Raymond,** COH, Inc.
**D. T. Tang,** U.S. Nuclear Regulatory Commission

# PREPARATION OF TECHNICAL INQUIRIES TO THE COMMITTEE ON CRANES FOR NUCLEAR FACILITIES

## INTRODUCTION

The ASME Committee on Cranes for Nuclear Facilities (CNF) will consider written requests for interpretations and revisions to CNF Standards and develop new requirements if dictated by technological development. The Committee's activities in this regard are limited strictly to interpretations of the requirements or to the consideration of revisions to the present Standard on the basis of new data or technology. As a matter of published policy, ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity and, accordingly, inquiries requiring such consideration will be returned. Moreover, ASME does not act as a consultant on specific engineering problems or on the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

All inquiries that do not provide the information needed for the Committee's full understanding will be returned.

## INQUIRY FORMAT

Inquiries shall be limited strictly to interpretations of the requirements or to the consideration of revisions to the present Standard on the basis of new data or technology.

Inquiries shall be submitted in the following format:

*(a) Scope.* The inquiry shall involve a single requirement or closely related requirements. An inquiry letter concerning unrelated subjects will be returned.

*(b) Background.* State the purpose of the inquiry, which would be either to obtain an interpretation of the Standard or to propose consideration of a revision to the present Standard. Provide concisely the information needed for the Committee's understanding of the inquiry, being sure to include reference to the applicable Standard, Edition, Requirements, Parts, Subparts, Appendices, paragraphs, figures, and tables. If sketches are provided, they shall be limited to the scope of the inquiry.

*(c) Inquiry Structure*

*(1) Proposed Question(s).* The inquiry shall be stated in a condensed and precise question format, omitting superfluous background information and, where appropriate, composed in such a way that "yes" or "no" (perhaps with provisos) would be an acceptable reply. The inquiry statement should be technically and editorially correct.

*(2) Proposed Reply(ies).* State what it is believed that the Standard requires. If, in the inquirer's opinion, a revision to the Standard is needed, recommended wording shall be provided.

*(d) Submittal.* The inquiry shall be submitted in typewritten form; however, legible, handwritten inquiries will be considered. It shall include the name, mailing address, and telephone number of the inquirer and be mailed to the following address:

Secretary
ASME Committee on Cranes for Nuclear
Facilities
Nuclear Department
Two Park Avenue
New York, NY 10016

# ASME NOG-1–2015
# SUMMARY OF CHANGES

Following approval by the ASME Committee on Cranes for Nuclear Facilities and ASME, and after public review, ASME NOG-1–2015 was approved by the American National Standards Institute on January 8, 2015.

ASME NOG-1–2015 includes the following changes identified by a margin note, **(15)**.

| *Page* | *Location* | *Change* |
|---|---|---|
| 8, 9 | 1160 | Updated |
| 14 | 4110 | Revised |
| | 4120 | Nomenclature of $P_{vi}$ revised |
| 33 | 4332.1 | Equations under "Design Factor *DFB*" revised |
| 34, 35 | 4341 | (1) First paragraph revised<br>(2) Original second paragraph deleted |
| | 4342 | Revised |
| | 4345 | First paragraph and subpara. (a) revised |
| 39 | 5100 | Paragraph added |
| 40 | 5161 | Nomenclature revised in its entirety |
| 42 | 5210 | Revised in its entirety |
| 43 | Table 5331.1-1 | First column head revised |
| 44–46 | Table 5332.1-1 | First column head revised |
| | Table 5333.1-1 | First column head revised |
| | 5411.3 | Revised in its entirety |
| | 5411.5 | Revised in its entirety |
| | Fig. 5411.5-1 | Revised in its entirety |
| | 5411.7 | (1) Subparagraph (b) revised<br>(2) Subparagraph (c) deleted |
| 51 | Table 5415.1-1 | (1) Penultimate column and Note (2) revised<br>(2) Note (4) added |
| 55, 57, 58, 60, 62 | 5423.1 | Subparagraph (c)(9) added |
| | 5427.1 | First paragraph revised |
| | 5430 | Subparagraph (a)(6) revised |
| 59 | Fig. 5427.1-1 | (1) Revised<br>(2) General Notes added |
| 60 | Fig. 5427.1-2 | (1) Revised<br>(2) General Notes added |
| 61 | Fig. 5430-1 | A-4 Drive illustration revised |

| *Page* | *Location* | *Change* |
|---|---|---|
| 62, 65 | 5440 | Subparagraph (a)(4) revised |
| 63 | Fig. 5440-1 | A-4 Drive illustration revised |
| 65 | 5451.1 | (1) Subparagraph (a) revised<br>(2) Last sentence in subpara. (b) deleted |
| 87 | 6415.1 | Subparagraph (c) added |
| 89, 90 | 6422.1 | Subparagraph (e) added |
| | 6422.2 | Last paragraph added |
| 91 | 6441 | (1) Revised in its entirety<br>(2) Paragraph 6441.1 added |
| 92 | 6444 | Revised in its entirety |
| 93, 94 | 6472.2 | Last sentence added to definition of $K_a$ nomenclature in subpara. (c) |
| 98 | 6473 | First sentence, eq. (12), and definition of *D* revised |
| 102 | 7240 | Subparagraph (l) revised |
| 104 | Table 7210-1 | Third entry in first column revised |
| 111 | 7423 | Subparagraph (b)(3) revised |
| 112, 113 | 7521.3 | Subparagraph (b)(12) added |
| 118 | I-5111 | Added |
| 120–124 | Mandatory Appendix II | Added |
| 142 | NUREG-0554/ASME NOG-1 Conformance Matrix | (1) Last entry in fourth column revised<br>(2) Last entry in last column deleted |

# RULES FOR CONSTRUCTION OF OVERHEAD AND GANTRY CRANES (TOP RUNNING BRIDGE, MULTIPLE GIRDER)

# Section 1000 Introduction



## 1100 GENERAL

Cranes covered under this Standard shall be designed in accordance with the Standard's requirements, but not necessarily with its recommendations. The word *shall* is used to denote a requirement, the word *should* is used to denote a recommendation, and the word *may* is used to denote permission, which is neither a requirement nor a recommendation.

### 1110 Scope

This Standard covers electric overhead and gantry multiple girder cranes with top running bridge and trolley used at nuclear facilities and components of cranes at nuclear facilities.

### 1120 Applications

This Standard applies to the design, manufacture, testing, inspection, shipment, storage, and erection of the cranes covered by this Standard.

### 1130 Responsibility

The cranes covered by this Standard are classified into three types (see para. 1150, Definitions, *crane, Type*), depending upon crane location and usage of the crane at a nuclear facility.

The owner shall be responsible for determining and specifying the crane type. The owner shall also be responsible for determining and specifying the environmental conditions of service, performance requirements, type and service level of coatings and finishes, and degree of quality assurance.

Determining the extent to which this Standard can be used, either in part or in its entirety, at other than nuclear facilities, shall be the responsibility of those referencing the use of this Standard.

### 1140 Environmental Conditions (Types I, II, and III Cranes)

#### 1141 Radiation

*(a)* The purchase specification shall specify the accumulated radiation dosage expected to be seen by the crane in the life of the nuclear facility.

*(b)* Components whose normal life could be reduced by the effects of the specified radiation shall be tabulated and submitted to the crane purchaser.

*(c)* Components whose failure, due to radiation, could result in loss of one of the single-failure-proof features that hold the load either shall be designed to withstand the specified radiation or shall have a specific replacement period. Where state-of-the-art is such that sufficient data are not available, periodic inspections shall be made by the purchaser to determine when replacement should be made.

#### 1142 Temperature

*(a)* The purchase specification shall specify the following temperature requirements in the area where the crane operates:

*(1)* maximum operating temperature

*(2)* minimum operating temperature

*(3)* ambient temperature for motors

*(4)* maximum construction temperature

*(5)* minimum construction temperature

*(b)* The crane shall be designed to withstand the effects of the specified temperatures, or the limitations of the crane's design concerning these temperature conditions shall be specified by the crane designer.

#### 1143 Pressure

*(a)* The purchase specification shall specify the following pressure requirements in the area where the crane operates:

*(1)* normal operating pressure

*(2)* any test or abnormal event of these pressures including the rate of change

*(b)* The crane shall be designed to withstand the effects of the specified pressures, or the limitations of the crane's design concerning these pressure conditions shall be specified by the manufacturer. Specifically, where there are changes in pressure, enclosures shall be vented.

**1144 Humidity**

*(a)* The purchase specification shall specify the humidity conditions in the area where the crane operates.

*(b)* The crane shall be designed to withstand the effects of the specified humidity, or the limitations of the crane's design concerning the humidity condition shall be specified by the manufacturer.

**1145 Chemical**

*(a) Spray Systems*

*(1)* If the crane may be subject to any spray systems, then the chemistry of the spray shall be specified in the purchase specification. Any restrictions on the use of materials due to the effects of the spray shall also be specified. Specifically, where a corrosive spray is present the possibility of $H_2$ generation exists and, therefore, the use of exposed aluminum, magnesium, galvanized steel, and zinc is to be minimized.

*(2)* The crane shall be designed to withstand the effects of the specified spray and shall not use the specified restricted materials. Any limitations of the crane's design concerning the spray condition and the use of any restricted materials shall be specified by the manufacturer prior to the manufacture of the crane.

*(b) Pools*

*(1)* If the crane's load block and wire rope are to be immersed, then the chemistry of the pool shall be specified in the purchase specification. Requirements for the materials and lubricants of the load block and wire rope shall also be specified to insure compatibility with the pool chemistry. In reactor and fuel pools, the lubricants shall basically be non-water-soluble and shall be free of halogenated compounds, halogens, mercury, and other deleterious materials.

*(2)* Load blocks and wire ropes that are to be immersed shall be lubricated with a lubricant that meets the specified lubrication requirements. Any limitations of the crane design concerning the pool chemistry and lubrication requirements shall be specified by the manufacturer.

**1146 Clearances.** The crane shall be designed to provide clearance between the crane components and the building and surrounding obstructions. At least 3 in. of clearance shall be provided between the highest point of the crane and the lowest overhead obstruction, after taking into account variables that affect the elevation of overhead structure relative to the crane, including but not limited to external loads such as snow and wind. The clearance between the ends of the crane and the building columns and other obstructions shall not be less than 2 in. with the crane centered on the runway rails. In addition, the crane must clear the obstructions when operational variables, including but not limited to maximum wheel float, crane skew, rail alignment, civil installation tolerances, and thermal expansion, are considered.

**1150 Definitions**

*acceptance criteria:* specified limits placed on characteristics of an item, process, or service defined in codes, standards, or other required documents.

*alligatoring:* see *checking*.

*appointed:* assigned specific responsibilities by the employer or the employer's representative.

*approval:* an act of endorsing or authorizing, or both.

*appurtenance:* a part that is attached to a component that has been completed.

*as-built data:* documentation describing a complete item.

*audit:* a planned and documented activity performed to determine by investigation, examination, or evaluation of objective evidence the adequacy of and compliance with established procedures, instructions, drawings, and other applicable documents, and the effectiveness of implementation. An audit should not be confused with surveillance or inspection activities performed for the sole purpose of process control or product acceptance.

*audit, external:* an audit of those portions of another organization's quality assurance program not under the direct control or within the organizational structure of the auditing organization.

*audit, internal:* an audit of those portions of an organization's quality assurance program retained under its direct control and within its organizational structure.

*authorized:* appointed by a duly constituted administrative or regulatory authority.

*auxiliary hoist:* see *hoist, auxiliary.*

*barrier:* a flexible material designed to withstand the penetration of water, water vapor, grease, or harmful gases.

*blisters:* bubble-like protrusions formed in a cured, or nearly cured, coating film; see ASTM D714-56 for photographic examples.

*boom, gantry crane:* an extension of the trolley runway, which may be raised or retracted to obtain clearance for gantry travel.

*boom, overhead crane:* a horizontal member mounted on the trolley to permit hoisting and lowering the load at a point other than directly under the hoist drum or trolley.

*brake:* a device, other than a motor, used for retarding or stopping motion by friction or power means.

*brake, drag:* a friction brake that provides a continuous retarding force having no external control.

*brake, emergency:* a brake for bridge and trolley that is released during normal operation and arranged to apply a retarding force when initiated by the operator during an emergency, or to automatically apply a retarding force upon loss of power.

*brake, mechanical load:* an automatic type of friction brake used for controlling loads in a lowering direction; this unidirectional device requires torque from the motor to lower a load but does not impose any additional load on the motor when hoisting a load.

*brake, parking:* a brake for the bridge and trolley that may be automatically or manually applied in an attempt to prevent horizontal motion by restraining wheel rotation.

*brake, service:* a brake for bridge or trolley used by the operator, during normal operation, to apply a retarding force.

*bridge:* that part of a crane consisting of two or more girders, trucks, end ties, footwalks, and drive mechanism, which carries the trolley or trolleys.

*bridge travel:* the crane movement in a direction parallel to the crane runway.

*bubbles:* gas pockets that rise through the wet coating film to the surface. An example of a bubble can be observed on runs shown in Fig. 10-8 of the ASTM Manual of Coating Work.

*bumper* (also known as buffer)*:* a device for reducing impact when a moving crane or trolley reaches the end of its permitted travel, or when two moving cranes or trolleys come into contact. This device may be attached to the crane, trolley, or runway stop.

*cab:* the operator's compartment on a crane.

*cab-operated crane:* see *crane, cab-operated.*

*calibration:* comparison of two instruments or measuring devices, one of which is a standard of known accuracy traceable to national standards, to detect, correlate, report, or eliminate by adjustment any discrepancy in accuracy of the instrument or measuring device being compared with the standard.

*cantilever frame:* a structural member that supports the trolley of a wall crane.

*cantilever gantry crane:* see *crane, gantry, cantilever.*

*carrier:* the transporting agency.

*certificate of conformance:* a document signed or otherwise authenticated by an authorized individual certifying the degree to which items or services meet specified requirements.

*certification:* the act of determining, verifying, and attesting in writing to the qualifications of personnel, processes, procedures, or items in accordance with specified requirements.

*certified test report:* see *report, certified test.*

*characteristic:* any property or attribute of an item, process, or service that is distinct, describable, and measurable.

*checking:* a defect in the coating manifested by slight breaks in the coating film that do not penetrate to the underlying surface per ASTM D660-44. Line-type checking is commonly known as alligatoring.

*classification:* the organization of items according to their susceptibility to damage during shipping, receiving, and storage. Classification does not relate to the function of the item in the completed system.

*cleanness:* a state of being clean in accordance with predetermined standards, usually implies freedom from dirt, scale, heavy rust, oil, or other contaminating impurities.

*clearance:* the distance from any part of the crane to a point of the nearest obstruction.

*collector, current:* a contacting device for collecting current from runway or bridge conductors.

*condition adverse to quality:* an all-inclusive term used in reference to any of the following: failures, malfunctions, deficiencies, defective items, and nonconformances. A significant condition adverse to quality is one that, if uncorrected, could have a serious effect on safety or operability.

*conductors, bridge:* the electrical conductors located along the bridge structure of a crane to provide power and control to the trolley(s).

*conductors, runway* (also known as main conductors)*:* the electrical conductors located along a crane runway to provide power or control to the crane.

*construction phase:* a period that commences with receipt of items at the construction site and ends when the components and systems are accepted by the owner or the owner's designated representative.

*control braking means:* a method of controlling speed by removing energy from the moving body or by imparting energy in the opposite direction.

*control braking means, dynamic:* a method of controlling speed by using the motor as a generator, with the energy being dissipated in resistors.

*control braking means, eddy current:* a method of controlling or reducing speed by means of an electrical induction load brake.

*control braking means, emergency:* a method of decelerating a drive when power is not available. The braking effort may be established as a result of action by the operator or automatically when power to the drive is interrupted.

*control braking means, mechanical:* a method of controlling or reducing speed by friction.

*controller:* a device or group of devices that serves to govern in some predetermined manner the power delivered to the apparatus to which it is connected.

*controller, manual:* a controller having all of its basic functions performed by devices that are operated by hand.

*controller, spring-return:* a controller that, when released, will return automatically to a neutral position.

*control panel:* an assembly of components (magnetic, static, hydraulic, pneumatic, etc.) that governs the flow of power to or from a motor or other equipment in response to signals from a master switch, pushbutton station, remote control, automatic program control, etc.

*corrective action:* measures taken to rectify conditions adverse to quality and, where necessary, to preclude repetition.

*countertorque (*also known as plugging*):* a method of control by which the power to the motor is reversed to develop torque in the direction opposite to the rotation of the motor.

*cracking:* a defect in the coating, manifested by a break in the coating film, that extends from the surface to substrate per ASTM D660-44. Irregular cracking is commonly known as mud cracking.

*crane:* a machine for lifting and lowering a load and moving it horizontally, with the hoisting mechanism an integral part of the machine. Cranes, whether fixed or mobile, are driven manually or by power, or by a combination of both.

*crane, cab-operated:* a crane controlled by an operator in a cab attached to the bridge or trolley.

*crane, floor-operated:* a crane that is controlled by a means suspended from the crane by an operator on the floor or an independent platform.

*crane, gantry:* a crane similar to an overhead crane except that the bridge for carrying the trolley or trolleys is supported on two or more legs running on fixed rails or other runway.

*crane, gantry, cantilever:* a gantry or semigantry crane in which the bridge girders or trusses extend transversely beyond the crane runway on one or both sides.

*crane, gantry, outdoor storage:* a gantry crane of long span usually used for storage of bulk material; the bridge girders or trusses are rigidly or nonrigidly supported on one or more legs. It may have one or more fixed or hinged cantilever ends.

*crane, overhead:* a crane with a multiple girder movable bridge carrying a movable or fixed hoisting mechanism and traveling on an overhead fixed runway structure.

*crane, polar:* a bridge or gantry crane that travels on a circular runway.

*crane, power-operated:* a crane whose mechanism is driven by electric, air, hydraulic, or internal combustion means.

*crane, pulpit-operated:* a crane operated from a fixed operator station not attached to the crane.

*crane, remote-operated:* a crane controlled by an operator not in a pulpit or in the cab attached to the crane, by any method other than a means suspended from a crane.

*crane, semigantry:* a gantry crane with one end of the bridge rigidly supported on one or more legs that run on a fixed rail or runway, the other end of the bridge being supported by a truck running on an elevated rail or runway.

*crane, standby:* a crane that is not in regular service but that is used occasionally or intermittently as required.

*crane, Type I:* a crane that is used to handle a critical load. It shall be designed and constructed so that it will remain in place and support the critical load during and after a seismic event, but does not have to be operational after this event. Single-failure-proof features shall be included so that any credible failure of a single component will not result in the loss of capability to stop and hold the critical load.

*crane, Type II:* a crane that is not used to handle a critical load. It shall be designed and constructed so that it will remain in place with or without a load during a seismic event; however, the crane need not support the load nor be operational during and after such an event. Single-failure-proof features are not required.

*crane, Type III:* a crane that is not used to handle a critical load; no seismic considerations are necessary, and no single-failure-proof features are required.

*crater:* the result of bubbles that rise through the wet coating film and burst at the surface creating a bowl-like depression (see Fig. 10-13 of the ASTM Manual of Coating Work for photographic examples).

*delamination:* separation of one coat or layer from another coat or layer of a coating system.

*design, final:* approved design output documents and approved changes thereto.

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

*designated representative:* an individual or organization authorized by the purchaser or owner to perform specified functions.

*design input:* those criteria, parameters, bases, or other design requirements upon which the detailed final design is based.

*design output:* documents such as drawings, specifications, and other documents defining technical requirements of structures, systems, and components.

*design process:* technical and management processes that commence with identification of design input and that lead to and include the issuance of design output documents.

*deviation:* a departure from specified requirements.

*diaphragm:* a plate or partition between opposite parts of a member, serving a purpose in the structural design of the member.

*disconnecting means:* a device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.

*document:* any written or pictorial information describing, defining, specifying, reporting, or certifying activities, requirements, procedures, or results.

*drift point:* a point on a travel motion master switch or on a manual controller that releases the brake while the motor is not energized; this allows for coasting.

*drum:* the cylindrical member around which the ropes are wound for lifting or lowering the load.

*end tie:* a structural member that connects the ends of the bridge girders to maintain squareness of the bridge.

*equalizer:* a device that compensates for unequal length of stretch of a rope.

*equipment, measuring and testing:* devices or systems used to calibrate, measure, gage, test, or inspect in order to control or acquire data to verify conformance to specified requirements.

*examination:* an element of quality verification consisting of investigation of items or services to determine conformance to specified requirements.

*exposed:* a condition in which hazardous objects are not adequately guarded or isolated (capable of being contacted inadvertently).

*fish eye:* a coating film defect consisting of holes or visible depressions in the coating film (see Figs. 10-11 and 10-12 of the ASTM Manual of Coating Work for photographic examples).

*flaking:* a defect in the coating film manifested by actual detachment of pieces of the film either from its substrate or from coating previously applied per ASTM D772-47 including photographic standards. Flaking is generally preceded by cracking, checking, or blistering and is the result of loss of adhesion.

*floor-operated crane:* see *crane, floor-operated*.

*gantry crane:* see *crane, gantry.*

*gantry crane boom:* see *boom, gantry crane.*

*gantry leg:* the structural member that supports a bridge girder or end tie from the sill.

*guideline:* a suggested practice that is not mandatory in programs intended to comply with a standard.

*handling:* an act of physically moving items by hand or mechanical machinery, not including transport modes.

*hoist:* a machinery unit that is used for lifting and lowering a load.

*hoist, auxiliary:* a supplemental hoisting unit, usually of lighter capacity and higher speed than the main hoist.

*hoist, main:* the primary hoist mechanism provided for lifting and lowering the rated load.

*hoist motion:* that motion which lifts or lowers a load.

*holding:* a friction brake for a hoist that is automatically applied and prevents motion when power is off.

*holiday:* a discontinuity in the coating film that exposes the substrate; types of holidays are pinholes, skips, or voids.

*hook, dual load path:* hook consisting of two independent load-attaching points that provides separate load paths between each attaching point and the load block. This may consist of a sister hook with hollow shank and an eye-bar through the sister hook shank. This provides alignment of the load-attaching points such as to maintain a vertical load balance at the center of lift. The load path redundancy provides protection against load drop should a failure occur within one load path.

*hydraulic:* a method of controlling or powering drive or braking by means of displacement of a liquid.

*in place:* remaining on the runway and retaining its physical integrity.

*inspection:* examination or measurement to verify whether an item or activity conforms to specified requirements.

*inspector:* a person who performs inspection activities to verify conformance to specific requirements.

*item:* an all-inclusive term used in place of any of the following: appurtenance, assembly, component, equipment, material, module, part, structure, subassembly, subsystem, system, or unit.

*lifting device:* a device that is not reeved onto the hoist ropes, such as hook-on buckets, magnets, grabs, and other supplemental devices used for ease of handling certain types of loads; the weight of these devices is considered part of the rated load.

*load:* the total superimposed weight on the load block or hook.

*load block:* the assembly of hook or shackle, swivel, bearing, sheaves, pins, and frames suspended by the hoisting rope; this shall include any items reeved in the hoisting ropes.

*load, credible critical:* combinations of lifted loads and plant seismic events that have probabilities of occurrence equal to or more than $10^{-7}$ times per calendar year at the plant of the crane installation. The critical loads handled by the crane, and their durations of lifts, shall be used in the calculations to determine the credible critical load to be considered for the crane in the crane design load combinations that include seismic loadings. The credible critical load shall be specified by the purchaser.

*load, critical:* any lifted load whose uncontrolled movement or release could adversely affect any safety-related system when such a system is required for unit safety or could result in potential off-site exposure in excess of the limit determined by the purchaser.

*load hangup:* the event in which the load block and/or load is stopped during hoisting by snagging or entanglement with heavy or fixed objects, thereby overloading the hoisting system and its supporting structure.

*load, rated:* the maximum load for which a crane or individual hoist is designed and built by a manufacturer.

*main hoist:* see *hoist, main*.

*man trolley:* see *trolley, man*.

*manufacturer:* one who constructs or fabricates an item to meet prescribed design requirements.

*material test report:* see *report, material test*.

*modification:* a planned change accomplished in accordance with the requirements and limitations of applicable codes, standards, and specifications.

*mud cracking:* see *cracking*.

*noncoasting mechanical drive:* a drive that results in automatically decelerating a trolley or bridge when power is not available.

*nonconformance:* a deficiency in characteristic, documentation, or procedure that renders the quality of an item or activity unacceptable or indeterminate.

*nondestructive examination:* methods for determining the integrity of structural materials without physically damaging the material; methods include visual, radiography, ultrasonic inspection, magnetic particle inspection, and liquid penetrant inspection.

*normal operating conditions, floor-operated crane:* conditions during which a crane is performing functions within the scope of the original design. Under these conditions, the operator is at the operating control devices that are attached to the crane but operated with the operator off the crane and with no other persons on the crane.

*objective evidence:* any documented statement of fact, other information, or record, either quantitative or qualitative, pertaining to the quality of an item, activity, or service based on observations, measurements, or tests that can be verified.

*orange peel:* a dimpled appearance of a dried coating film that resembles the texture and appearance of an orange peel.

*outdoor storage gantry crane:* see *crane, gantry, outdoor storage*.

*overhead crane:* see *crane, overhead*.

*overhead crane boom:* see *boom, overhead crane*.

*overload:* any load greater than the rated load.

*overspray:* spraying of coating on adjacent surfaces; texture can range from that of sandpaper to orange peel (see Fig. 10-5 of the ASTM Manual of Coating Work for photographic examples).

*owner:* the organization legally responsible for the construction and/or operation of a nuclear facility including, but not limited to, one who has applied for or who has been granted a construction permit or operating license by the regulatory authority having lawful jurisdiction.

*package:* the shipping container plus the contents of the container.

*package unit:* any assembly of mechanical and/or electrical components and parts that can be disassembled without destroying the integrity of the individual parts.

*peeling:* separation of one or more coats or layers of a coating system from the substrate.

*pinhole:* a minute hole through the thickness of a coating film, allowing exposure of substrate (see Fig. 10-14 of the ASTM Manual of Coating Work for photographic examples).

*plugging:* a control function that provides braking by reversing the motor line voltage polarity or phase sequence so that the motor develops a countertorque that exerts a retarding force.

*pneumatic:* a method of controlling or powering a drive or braking by means of compressing a gas.

*polar crane:* see *crane, polar*.

*power-operated crane:* see *crane, power-operated*.

*procedure:* a document that specifies or describes how an activity is to be performed.

*procurement document:* purchase requisitions, purchase orders, drawings, contracts, specifications, or instructions used to define requirements for purchase.

*pulpit-operated crane:* see *crane, pulpit-operated*.

*purchaser:* the organization responsible for establishment of procurement requirements and for issuance or administration, or both, of procurement documents.

*push-button station, pendant:* means suspended from the crane for operating the controllers from the floor or other level beneath the crane.

*qualification, personnel:* the characteristics or abilities gained through education, training, or experience, as measured against established requirements, such as standards or tests, that qualify an individual to perform a required function.

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

*qualified procedure:* an approved procedure that has been demonstrated to meet the specified requirements for its intended purpose.

*quality assurance:* all those planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service.

*quality assurance record:* a completed document that furnishes evidence of the quality of items and/or activities affecting quality.

*quality control:* those quality assurance actions that provide a means to control and measure the characteristics of an item, process, or facility to established requirements.

*rail sweep:* a mechanical device attached to the crane but located in front of the crane leading wheels to deflect any obstructions.

*receiving:* taking delivery of an item at a designated location.

*regenerative:* a method in which the electrical energy generated by the motor is fed back into the power system.

*remote-operated crane:* see *crane, remote-operated*.

*repair:* the process of restoring a nonconforming characteristic to a condition, such that the capability of an item to function reliably and safely is unimpaired, even though that item still does not conform to the original requirement.

*report, certified test:* a document signed by a qualified party that contains sufficient data and information to verify the actual properties of items and the actual results of all required tests.

*report, load summary:* the report provided by the manufacturer that furnishes the numerical values of the crane loads at the crane-building interfaces for the load combinations of each category of loads listed for the structural design of the crane.

*report, material test:* a report from the material supplier that identifies the furnished material in terms of heat number, physical and chemical properties, etc., as appropriate.

*rework:* the process by which an item is made to conform to original requirements by completion or correction.

*right of access:* the right of a purchaser or designated representative to enter the premises of a supplier for the purpose of inspection, surveillance, or quality assurance audit.

*rope:* refers to wire rope unless otherwise specified.

*run:* the flow of an excessively applied coating that results in an elongated pattern of irregular coating films over a small vertical or sloped surface area such as a point or an angle (see Fig. 10-8 of the ASTM Manual of Coating Work for photographic examples).

*running sheave:* a sheave that rotates as the load block is raised or lowered.

*runway:* an assembly of rails, beams, girders, brackets, and framework on which the crane travels.

*sag:* the flow of an excessively applied coating that results in a broad pattern of irregular coating films over a large vertical or sloped surface area (see Fig. 10-9 of the ASTM Manual of Coating Work for photographic examples).

*scaling:* detachment of coating film from substrate.

*semigantry crane:* see *crane, semigantry*.

*service:* the performance of activities such as design, fabrication, inspection, nondestructive examination, repair, or installation.

*shall:* indicates that which is mandatory and must be followed.

*should:* indicates a recommendation, the advisability of which depends on the facts in each situation.

*side pull:* the portion of the hoist pull acting horizontally when the hoist lines are not operated vertically.

*sill:* a horizontal structural member that connects the lower ends of two or more legs of a gantry crane on one runway.

*single-failure-proof features:* those features that are included in the crane design such that any credible failure of a single component will not result in the loss of capability to stop and hold the critical load within facility acceptable excursion limits.

*skip:* the unintentional omission of coating from an area of the substrate.

*span:* the horizontal distance center-to-center of runway rails.

*special process:* a process, the results of which are highly dependent on the control of the process or the skill of the operators, or both, and in which the specified quality cannot be readily determined by inspection or test of the product.

*specification:* a concise statement of a set of requirements to be satisfied by a product, material, or process.

*standby crane:* see *crane, standby*.

*stop:* a device to limit travel of a trolley or crane bridge; this device normally is attached to a fixed structure and normally does not have energy absorbing ability.

*storage:* the act of holding items in a storage facility.

*storage facility:* area designated and prepared for holding of items.

*structural weld:* a weld that is directly stressed by the crane load.

*substrate:* the uncoated base surface to which the coating is to be applied.

*supplier:* any individual or organization who furnishes items or services in accordance with a procurement document; an all-inclusive term used in place of any of the following: vendor, seller, contractor, subcontractor, fabricator, consultant, and their subtier levels.

*surveillance:* the act of monitoring or observing to verify whether an item or activity conforms to specified requirements.

*switch:* a device for making, breaking, or changing connections in an electric circuit.

*switch, emergency stop:* a manually operated switch to cut off electric power independently of the regular operating controls.

*switch, limit:* a switch that is operated by some part or motion of a power-driven machine or equipment to alter or disconnect the electric circuit associated with the machine or equipment.

*switch, main:* a switch on the crane controlling the main power supply to the crane.

*switch, master:* a switch that dominates the operation of contactors, relays, or other remotely operated devices.

*temperature, minimum operating:* the minimum ambient temperature at which the crane is operated, either during the construction phase or plant in-service phase of use of the crane.

*test, break strength:* a physical test to destruction performed on a sample of an item to verify the rated strength of that item.

*test, dynamic load:* a test wherein designated loads are hoisted, lowered, rotated, or transported through motions and accelerations required to simulate handling of the intended item.

*test, proof load:* a physical load test, with magnitude to be as specified but always in excess of the design load.

*testing:* an element of verification for the determination of the capability of an item to meet specified requirements by subjecting the item to a set of physical, chemical, environmental, or operational conditions.

*traceability:* the ability to trace the history, application, or location of an item and like items or activities by means of recorded identification.

*transit carriers, closed:* trucks, trailers, railroad cars, barges, aircraft, or ships that do provide protection of items from the environment.

*transit carriers, open:* trucks, trailers, railroad cars, barges, aircraft, or ships that do not provide protection of items from the environment.

*transportation mode:* a method identified by the conveyance used for transportation of items. It includes any motor vehicle, ship, railroad car, or aircraft; each cargo-carrying body (trailer, van, boxcar, etc.) is a separate vehicle.

*trolley:* the unit that travels on the bridge rails and supports the load block.

*trolley, man:* a trolley having an operator's cab attached to it.

*trolley frame:* an assembly consisting of two side frames or trucks that are connected together by one or more load girts to form a one-piece unit capable of transmitting the load to the crane bridge without undue deflection. The hoist machinery and supports for the sheaves or equalizer are assembled into and supported by the trolley frame.

*truck:* the unit, consisting of a crane, wheels, bearings, and axles, that supports the bridge girders, the end ties of an overhead crane, or the sill of a gantry crane.

*two-blocking:* the act of hoisting (beyond the intended upper limit) in which the load block comes into physical contact with the head block (upper block) or its supporting structure, preventing further upward movement of the load block and creating an overload of the rope reeving system and hoisting machinery.

*upper block:* a fixed block located on a trolley, that, through a system of sheaves, bearings, pins, and frames, supports the load block and its load.

*use-as-is:* a disposition permitted for a nonconforming item when it can be established that the item is satisfactory for its intended use.

*verification:* the act of reviewing, inspecting, testing, checking, auditing, or otherwise determining and documenting whether items, processes, services, or documents conform to specified requirements.

*visual inspection:* a macroscopic examination to determine conformance to quality requirements.

*void:* an area of missing coating through which the substrate or base coat is visible.

*waiver:* documented authorization to depart from specified requirements.

*web plate:* the vertical plate connection and upper and lower flanges or cover plates of a girder.

*wrap:* a flexible material formed around the item or package, to exclude dirt and to facilitate handling, marking, or labeling.

## 1160 References (15)

The following is a list of codes and standards referenced in NOG-1. These codes and standards apply to the extent invoked at the point of reference.

AGMA 9005-E02, Industrial Gear Lubrication

ANSI/AGMA 2001-C95, Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth

Publisher: American Gear Manufacturers Association (AGMA), 1001 North Fairfax Street, Suite 500, Alexandria, VA 22314 (www.agma.org)

The following three documents are contained in the *AISC Manual of Steel Construction (ASD), Ninth Edition:*

Code of Standard Practice for Steel Buildings and Bridges, March 7, 2000
Specification for Structural Joints Using ASTM A325 or A490 Bolts, June 23, 2000
Specification for Structural Steel Buildings Allowable Stress Design and Plastic Design, June 1, 1989
Publisher: American Institute of Steel Construction (AISC), 1 East Wacker Drive, Suite 700, Chicago, IL 60601 (www.aisc.org)

AISE TR No. 1, 1991, DC Mill Motors
AIST/AISE TR No. 6, 2005, Specification for EOT Cranes for Steel Mill Service
Publisher: Association for Iron & Steel Technology (AIST), 186 Thorn Hill Road, Warrendale, PA 15086 (www.aist.org)

ASME B30.2-2011, Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist)
ASME B30.10-2009, Hooks
ASME NQA-1–2012, Quality Assurance Requirements for Nuclear Facility Applications
Publisher: The American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, P.O. Box 2900, Fairfield, NJ 07007-2900 (www.asme.org)

ASTM A275/A275M-98, Magnetic Particle Examination of Steel Forgings
ASTM A370-02, Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A388/A388M-01, Standard Practice for Ultrasonic Examination of Heavy Steel Forgings
ASTM A435/A435M-90, Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates
ASTM D660-44, Standard Test Method for Evaluating Degree of Checking of Exterior Paints
ASTM D714-56, Standard Test Method for Evaluating Degree of Blistering of Paints
ASTM D772-47, Standard Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints
ASTM D5144-00, Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants
ASTM D5161-96, Standard Guide for Specifying Inspection Requirements for Coating and Lining Work (Metal Substrates)
ASTM E165-02, Standard Test Method for Liquid Penetrate Examination
ASTM E380-93, Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)
ASTM E709-01, Standard Guide for Magnetic Particle Examination
Manual of Coating Work
Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org)

AWS D1.1/D1.1M-2010, Structural Welding Code — Steel
Publisher: American Welding Society (AWS), 8669 NW 36 Street, No. 130, Miami, FL 33166 (www.aws.org)

CMAA 70-2010, Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes
Publisher: Crane Manufacturers Association of America, Inc. (CMAA), 8720 Red Oak Boulevard, Charlotte, NC 28217 (www.mhia.org/industrygroups/cmaa)

NEMA ICS 1-2000 (R2005, R2008), Industrial Control and Systems: General Requirements
NEMA ICS 2-2002 (R2005), Industrial Control and Systems: Controllers, Contactors, and Overload Relays Rated 600 Volts (R2005)
NEMA ICS 3-1993, Industrial Control and Systems: Factory Build Assemblies
NEMA ICS 6-1993 (R2001, R2006), Industrial Control and Systems Enclosures
Publisher: National Electrical Manufacturers Association (NEMA), 1300 North 17th Street, Rosslyn, VA 22209 (www.nema.org)

NFPA 70-2014, National Electrical Code (NEC)
Publisher: National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169 (www.nfpa.org)

OSHA Safety and Health Standards, Title 29, Code of Federal Regulations Part 1910 (29 CFR 1910), Occupational Safety and Health Standards
Publisher: U.S. Department of Labor — Occupational Safety & Health Administration (OSHA), U.S. Department of Labor, 200 Constitution Avenue, Washington, DC 20210 (www.osha.gov)

SNT-TC-1A-1996, Recommended Practices for Nondestructive Testing Personnel Qualification and Certification
Publisher: American Society for Nondestructive Testing (ASNT), 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228 (www.asnt.org)

Systems and Specifications, Steel Structures Painting Manual, Volume 2, 8th Edition, 2000
Publisher: SSPC: The Society for Protective Coatings, 40 24th Street, Pittsburgh, PA 15222 (www.sspc.org)

### 1170 Nomenclature

The nomenclature used in this Standard is listed and defined in the Section in which it is used.

### 1180 Conversion Factors

Conversion factors, including metric equivalents, are provided in Mandatory Appendix I.

### 1190 Markings

*(a)* The rated load markings on the crane and on the hoist unit(s) shall be in accordance with the criteria of ASME B30.2.

*(b)* Additional manufacturer's identification markings, multiple hoist markings, and warning markings shall also be in accordance with ASME B30.2.

*(c)* For Type I cranes, the maximum critical load (MCL) shall be marked on the crane and hoist in lieu of the rated load markings as identified in (a) above, using the terminology MCL as part of the marking.

*(d)* For Type I cranes that lift loads in excess of the MCL, the design rated load (DRL) shall also be marked on the crane and hoist(s).

# Section 2000
# Quality Assurance

## 2100 REQUIREMENTS

*(a)* The quality assurance program of the Manufacturer of Types I and II cranes shall meet the Basic and Supplemental Requirements of ASME NQA-1, or shall meet the Quality Assurance Requirements specified by the owner.

*(b)* A specific quality assurance program for manufacturers of Type III cranes is not required unless specified in the procurement documents.

*(c)* A specific quality assurance program for mechanical components for Type II cranes is not required unless specified in the procurement documents.

*(d)* A specific quality assurance program for suppliers of electrical components for Types I and II cranes is not required unless specified in the procurement documents.

*(e)* A specific quality assurance program for suppliers of Type I crane structural and mechanical components that are not listed in Table 7210-1, and for Type II crane structural components that are not listed in Table 7210-2, is not required unless specified in the procurement documents.

*(f)* The quality assurance program for packaging, shipping, receiving, storage, and handling of Types I and II cranes shall be in conformance with Section 8000.

# Section 3000 Coatings and Finishes

## 3100 COATING SERVICE LEVELS

The owner shall specify either coating service level I or II as defined below.

*(a) Coating Service Level I.* For use in areas where coating failure could adversely affect the operation of post-accident fluid systems and, thereby, impair safe shutdown. With few exceptions, coating service level I applies to coatings inside a nuclear power plant's primary containment.

*(b) Coating Service Level II.* For use in areas where coating failure could impair, but not prevent, normal operating performance. The function of coating service level II coatings is to provide corrosion protection and decontaminability in those areas outside primary containment subject to radiation exposure and radionuclide contamination. Coating service level II also applies to coatings in nonradiation areas.

## 3200 SPECIFIC REQUIREMENTS FOR COATING SERVICE LEVELS

### 3210 Requirements for Coating Service Level I

*(a)* Coating requirements for coating service level I shall be in accordance with ASTM D5144.

*(b)* In accordance with ASTM D5144, coating service level I requires a quality assurance program.

*(c)* Inspection and testing of coatings for coating service level I shall be in accordance with ASTM D5144. Specific coating inspections shall be specified by the owner, dependent upon the coating system being used. See ASTM D5161 for selecting and specifying the appropriate inspection requirements.

### 3220 Requirements for Coating Service Level II

*(a)* Coating requirements for coating service level II shall be as specified by the owner. The owner may invoke applicable sections of ASTM D5144.

*(b)* Quality assurance requirements for coating service level II shall only apply as specified by the owner.

*(c)* Inspection and testing requirements for coating service level II shall apply as specified by the owner.

### 3230 Additional Requirements Applicable to All Coatings

Additional requirements for coatings and finishes are listed in (a) through (o) below. Further information for coatings and finishes is provided in Nonmandatory Appendix A, para. A-3240.

*(a)* If not specified by the owner, the type of coating will be determined by the manufacturer to meet the specified environmental conditions of service and coating service level. Specifically, the selected coatings shall be suitable for any specified radiation, temperature, and chemical immersion or chemical spray environment.

*(b)* Welding through coatings shall not be allowed unless the coating system is specifically designed and formulated as a weldable system and documentation can be provided by the coating manufacturer to attest to this capability. The use of these coatings shall be approved by the owner.

*(c)* Surfaces exposed to the environment, but inaccessible after assembly, such as wheel wells and hubs, shall be coated prior to assembly.

*(d)* Coating of interior or enclosed surfaces of the equipment, such as inside a welded box section, is not required by this Standard.

*(e)* Contact surfaces of friction-type joints to be joined by high-strength bolts shall not be coated with specified coating system except for organic or inorganic zinc coating systems not prohibited by para. 1145.

*(f)* Machined mating surfaces and other surfaces not normally protected by the specified coating system, such as hooks, hook nuts, wheel treads, rails, gears, shafts, pinions, couplings, drum grooves, sheave grooves, and brake wheels, shall be protected by means of an appropriate preservative for shipment and/or storage. The manufacturer shall specify which preservatives must be removed by the owner for proper operation of the equipment. Other preservatives may be removed by the owner after installation of the equipment.

*(g)* Forced curing or drying of the coating system shall not be performed unless recommended by the coating manufacturer.

*(h)* Fillers, sealants, and caulking compounds shall be compatible with the coating system.

*(i)* Finished components, such as motors, brakes, gear reducers, limit switches, electrical dials and gauges, control enclosures, brake rectifier cabinets, control masters, safety switches, auxiliary heaters, push-button stations, transformers, manual magnetic disconnects, light fixtures, reactors, resistor banks, protective guards, cross-shaft bearing blocks, unitized hoists, interior of control cabinets, festoon trolley cable spacer systems cab interiors, and radio control equipment, may be furnished with

conventional coatings unless otherwise specified by the owner.

*(j)* For coating service level I applications, the equipment manufacturer shall supply the estimated surface area of exposed parts provided with conventional coatings.

*(k)* Nameplates and warning labels of factory finished components that are recoated shall be masked to preserve legibility.

*(l)* Items such as fasteners and conduits shall be supplied with the specified coating system, galvanized, or plating. Galvanizing or plating shall be subject to the requirements of para. 1145. When specifically requested by the owner, a list of galvanized or plated parts shall be provided by the equipment manufacturer.

*(m)* Surface contaminants, such as grease and oil, detected after blasting shall be removed to produce the surface conditions required by the Society for Protective Coatings (SSPC) surface preparation requirement.

*(n)* If there is visible deterioration of the surface beyond the specified SSPC preparation, repreparation of the surface shall be required.

*(o)* Preparation of surface shall be accomplished by the methods originally used, except that small areas requiring repair or touchup where conventional blasting is not desirable may be reprepared by one of the following methods. These methods are listed in descending order of effectiveness.

*(1)* Vacuum blasting to clean an abrasive finish with a minimum 2.0-mil profile; the minimum blasting air pressure shall be 50 psi at the blasting nozzle.

*(2)* Power tool cleaning using grinding wheels, sanding discs, or other devices to provide a minimum 2-mil profile in accordance with SSPC SP-3; the use of a needle gun to roughen the surface after grinding is recommended.

*(3)* Hand sanding to obtain as clean a surface as possible in accordance with SSPC SP-2; or wire brushing in accordance with SSPC SP-2.

# Section 4000
# Requirements for Structural Components

## 4100 GENERAL

(15) **4110 Scope**

Section 4000 specifies design criteria, materials, and fabrication requirements for structural components of Types I, II, and III cranes. Unless otherwise stated, the design requirements and allowable stresses are based on Allowable Stress Design (ASD) using classical Mechanics of Materials/Strength of Materials methodologies. Structural components are identified in para. 4400.

(15) **4120 Nomenclature**

The nomenclature listed herein is used in the equations in Section 4000. For further information on nomenclature, application, and units of measurement, see the Section 4000 references noted in parentheses.

$A_b$ = tensile stress area of bolt, in.$^2$ (para. 4323)
$a$ = plate length for direction parallel to the direction of compression force (Table 4332.1-1); unsupported length of web plate between transverse (vertical) stiffeners, in. (para. 4334)
$b$ = plate width for direction perpendicular to the direction of the compressive force (para. 4331); unsupported length of web plate between longitudinal stiffeners, in. (Table 4332.1-1)
$b_w$ = distance between web plates, in. (para. 4333)
$C$ = coefficient for spacing of transverse stiffeners of web (para. 4334)
$C_c$ = column slenderness ratio separating elastic and inelastic buckling (para. 4312)
$C_m$ = coefficient applied to bending term in interaction formula for prismatic members, and dependent upon column curvature caused by applied moments (para. 4321)
$DF$ = design factor (para. 4312)
$DFB$ = design factor for buckling (paras. 4332 and 4333)
$E$ = modulus of elasticity of the materials (29,000,000 psi for carbon steel) (paras. 4312, 4321, and 4331)
$h$ = depth of web, in. (para. 4333)
$K$ = buckling coefficient (paras. 4331, 4332.1, and 4333)
$K_\sigma$ = effective length factor for compression (paras. 4331, 4332.1, and 4333)
$K_\tau$ = buckling coefficient for shear (paras. 4331 and 4332.1)
$k$ = effective length factor (paras. 4312, 4321, 4331, and 4332.1)
$l$ = unbraced length of member (para. 4312)
$l_b$ = actual unbraced length in plane of bending (para. 4333)
$M$ = bending moment at end of member in plane of bending being considered
$M_1$ = smaller of end moments in member in plane of bending being considered (para. 4321)
$M_2$ = larger of end moments in member in plane of bending being considered (para. 4321)
$N$ = modifying coefficient for loading condition (paras. 4312 and 4321)
$P_a$ = abnormal event load (paras. 4130 and 4140)
$P_{cn}$ = construction lifted load (paras. 4130 and 4140)
$P_{co}$ = credible critical load with operating basis earthquake (OBE) (paras. 4130 and 4140)
$P_{cs}$ = credible critical load with safe shutdown earthquake (SSE) (paras. 4130 and 4140)
$P_{db}$ = bridge or gantry frame dead load (paras. 4130 and 4140)
$P_{dt}$ = trolley dead load (paras. 4130 and 4140)
$P_{eo}$ = OBE load (paras. 4130 and 4140)
$P_{es}$ = SSE load (paras. 4130 and 4140)
$P_{hl}$ = longitudinal horizontal load (paras. 4130 and 4140)
$P_{ht}$ = transverse horizontal load (paras. 4130 and 4140)
$P_{lc}$ = critical load (paras. 4130 and 4140)
$P_{lh}$ = load hangup forces at maximum hoisting speed, including inertia
$P_{lr}$ = design rated lift load (paras. 4130 and 4140)
$P_p$ = plant operations induced loads transmitted to the crane (paras. 4130 and 4140)
$P_{tb}$ = two-blocking forces at maximum hoisting speed, including inertia of rotating hoist components
$P_{tp}$ = containment static test pressure load (paras. 4130 and 4140)
$P_{vi}$ = hoisting impact load (paras. 4130 and 4140)
$P_{wd}$ = plant design basis wind load (paras. 4130 and 4140)
$P_{wo}$ = crane operating wind load (paras. 4130 and 4140)
$P_{wt}$ = tornado wind load (paras. 4130 and 4140)
$R$ = structural bolt loading condition factor (para. 4323), or combined modal response of each

of the three orthogonal components of earthquake motion (para. 4153.10)
$R_f$ = ratio of frequencies of crane and runway system (para. 4153.5)
$R_m$ = ratio of masses of crane and runway system (para. 4153.5)
$r$ = radius of gyration, in. (para. 4312)
$T_b$ = specified pretension load of the bolt, lb (para. 4323)
$t$ = thickness of plate, in. (paras. 4331, 4333, and 4334)
$\alpha$ = ratio of plate length to width (Table 4332.1-1)
$\beta$ = stress ratio (Table 4332.1-1)
$\theta$ = rotation at node
$\mu$ = Poisson's ratio (para. 4331)
$\sigma$ = computed axial stress, psi (para. 4321)
$\sigma_a$ = allowable axial stress, psi (para. 4321)
$\sigma_{ab}$ = allowable bending stress in the plane of bending being considered, psi (para. 4321)
$\sigma_{ac}$ = allowable compressive stress without consideration for buckling, psi (para. 4321)
$\sigma_{at}$ = allowable tensile stress (para. 4323)
$\sigma_b$ = computed stress in plane of bending, psi (para. 4321)
$\sigma_c$ = computed compressive stress, psi (para. 4332)
$\sigma_{ce}$ = equivalent compressive stress, psi (para. 4332.1)
$\sigma_{cr}$ = critical comparison buckling stress, compressive stresses only, psi (para. 4331)
$\sigma_{crc}$ = critical comparison buckling stress, compressive and shear stresses in combination, psi (para. 4332)
$\sigma_e$ = Euler buckling stress, psi
$\sigma_{e'}$ = Euler buckling stress divided by a modifying coefficient for design factor, psi (para. 4321)
$\sigma_p$ = proportional limit, psi (para. 4331)
$\sigma_y$ = specified minimum yield stress of the material, psi (paras. 4311 and 4323)
$\tau$ = computed shear stress, psi (para. 4333)
$\tau_a$ = allowable shear stress, psi (para. 4323)
$\tau_{cr}$ = shear critical buckling stress, psi (para. 4331)

## 4130 Description of Loads

The loads described herein are the loads to be used for the analysis and design of the structural components of the crane. The loads are to be combined as outlined in para. 4140. All loads described, except the crane dead loads, shall be stated by the purchaser in the purchase specification.

### 4131 Dead Loads

*(a) Trolley, $P_{dt}$.* The total weight of the trolley including all machinery and equipment attached thereto.

*(b) Bridge or Gantry Frame, $P_{db}$.* The total weight of the bridge or gantry frame structure including all machinery and equipment attached thereto, trucks, wheels, and end ties.

### 4132 Live Loads

*(a) Rated Load, $P_{lr}$.* The design rated load to be lifted and transported by the crane that by definition is not considered as the critical load. An allowance for lifting accessories that are not part of the crane, such as yokes, spreader beams, etc., is to be included in the design rated load.

*(b) Critical Load, $P_{lc}$.* For the definition of *critical load*, see para. 1150. In addition to listing each critical load, the purchaser shall furnish the duration in hours per year that each critical load is expected to be on the crane hook. An allowance for lifting accessories is to be included in each critical load.

*(c) Construction Load, $P_{cn}$.* The maximum expected construction load to be lifted and transported by the crane during the plant construction phase, prior to its use as a plant operating crane.

*(d) Credible Critical Load, $P_{co}$ and $P_{cs}$.* $P_{co}$ is the weight of lifted load that may be considered in combination with the operating basis earthquake (OBE). $P_{cs}$ is the weight of lifted load that may be considered in combination with the safe shutdown earthquake (SSE).

Alternatively, $P_{co}$ and $P_{cs}$ may be defined to be lifted loads in credible combinations with seismic events other than OBE and SSE. If this alternative method is used, the appropriate substitution for $P_{eo}$ and $P_{es}$ shall be made in load combinations $P_{c10}$ and $P_{c12}$.

The loads and seismic events shall be specified by the purchaser.

### 4133 Normal Operating Dynamic Loads

*(a) Hoisting Impact Load (HIL), $P_{vi}$.* The hoisting impact load is the result of sudden lifting of a load and other loading uncertainties that occur during normal crane operation. This load shall be determined by applying an HIL factor to the lifted load, including load block and attachments. The HIL factor shall be 0.5% of the hoisting speed in feet per minute, but not less than 15% nor more than 50%.

$$\text{HIL factor} = 0.15 \le 0.005 \times \text{hoist speed (ft/min)} \le 0.50$$

*(b) Bridge and Trolley Travel Drive Inertia Forces (TDIF), $P_{hb}$ and $P_{ht}$.* Travel drive inertia forces result from the acceleration or deceleration of the crane bridge or trolley and depend on the magnitude of torque applied to the drive wheels. This force shall be determined by applying a TDIF factor to the lifted load and weight of the crane components, including load block and attachments, and shall be imposed on the crane in the direction of bridge and trolley travel. The resulting inertia force in the direction of bridge travel that corresponds to the trolley weight and lifted load, including load block and attachments, may be equally divided between the two bridge girders.

The TDIF factor shall be 7.8% of the acceleration or deceleration rate (ft/sec$^2$) but not less than 2.5%. The resulting drive inertia force is based on 250% of the nominal acceleration or deceleration rate produced by either the drive motor or brake. Additional consideration should be given to a cab-operated crane that is equipped with a pedal-operated or power-assist braking system. Due to the nature of these braking systems, the deceleration rates are limited by the frictional force between the braked wheels and rail (i.e., maximum force when sliding occurs).

$$\text{TDIF factor} = (2.50 / 32.2) \times \text{accel. or decel. rate (ft/sec}^2) \geq 0.025$$
$$= 0.078 \times \text{accel. or decel. rate (ft/sec}^2) \geq 0.025$$

For polar cranes, the TDIF factor corresponding to the trolley and lifted load, including load block and attachments, that results from either the acceleration or deceleration of the bridge, may be adjusted by the ratio of the location of the trolley and lifted load to the radius of the crane runway rail, both relative to the center of bridge rotation. However, in order to account for possible load swing, the inertia force that corresponds to the lifted load, including load block and attachments, shall not be less than 1.5% of these loads. Further, the inertia force that corresponds to bridge component weights, including distributive weight of the girders, may be adjusted by the ratio of the location of the component relative to the center of bridge rotation, to the radius of the crane runway rail. The resulting forces at each end of the polar crane bridge are in opposite directions.

**4134 Wind Loads.** The following wind loads are to be considered to act in any direction:

*(a) Operating Wind,* $P_{wo}$. The maximum wind load under which the crane will be permitted to operate. If none is stipulated by the purchaser, then the nominal wind load specified in CMAA 70 shall be used.

*(b) Design Wind,* $P_{wd}$. The plant design basis wind load resulting from the 100 yr recurrence, "fastest-mile of wind." Under this loading, the crane will not be operational, but be secured.

*(c) Tornado Wind,* $P_{wt}$. The plant design basis tornado loads. Tornado pressure differentials associated with the plant design basis tornado shall be included in the loading. Tornado-generated missiles shall be considered. The purchaser shall be responsible for the missile parameters and method of evaluation of tornado loads and tornado-generated missiles. Under these loadings, the crane will not be operational, but be secured. Indoor cranes may be subjected to the design basis tornado if the building enclosures have been designed to fail.

### 4135 Normal Plant Operating Loads

*(a) Plant Operation Induced Loads,* $P_p$. The loads imposed on the crane through the supporting structure due to normal operation of plant equipment. The crane is not operating.

*(b) Static Test Pressure Load,* $P_{tp}$. The overpressure imposed on the crane due to the static test pressure load for the structure enclosing the crane. This load applies only to those cranes housed within containments. The crane is not operating.

### 4136 Seismic and Abnormal Events Loads

*(a) Safe Shutdown Earthquake,* $P_{es}$. The site SSE parameters shall be used in the seismic analysis of the bridge crane or the gantry crane, following the procedures outlined in para. 4140.

*(b) Operating Basis Earthquake,* $P_{eo}$. The site OBE parameters shall be used in the seismic analysis of the bridge crane or the gantry crane, following the procedures outlined in para. 4140.

*(c) Abnormal Event Loads,* $P_a$. Loads caused by failure of plant equipment that impose jet or missile loads on the crane. The purchaser shall be responsible for the effects of, and shall establish the criteria for, these loads.

## 4140 Load Combinations

The following tabulated loads and their designations are described in para. 4120. The various load combinations, using the load designations, are listed herein. All load combinations are applicable to Types I and II cranes, whereas the crane operational loads and the construction loads combinations are applicable to the Type III cranes.

| Load | Load Designation |
|---|---|
| Trolley dead load | $P_{dt}$ |
| Bridge/gantry dead load | $P_{db}$ |
| Rated load | $P_{lr}$ |
| Critical load | $P_{lc}$ |
| Credible critical load with OBE | $P_{co}$ |
| Credible critical load with SSE | $P_{cs}$ |
| Construction load | $P_{cn}$ |
| Hoisting impact load | $P_{vi}$ |
| Load hangup forces | $P_{lh}$ |
| Two-blocking forces | $P_{tb}$ |
| Bridge horizontal inertia load | $P_{hb}$ |
| Trolley horizontal inertia load | $P_{ht}$ |
| Operating wind load | $P_{wo}$ |
| Design wind load | $P_{wd}$ |
| Tornado wind load | $P_{wt}$ |
| Plant operation induced loads | $P_p$, $P_{tp}$ |
| Loads due to an SSE seismic event | $P_{es}$ |
| Loads due to an OBE seismic event | $P_{eo}$ |
| Abnormal event loads | $P_a$ |

*(a) Crane Operational Loads*[1]

$$P_{C1} = P_{db} + (P_{dt} + P_{lr})$$

$$P_{C2} = P_{db} + (P_{dt} + P_{lr}) + P_{vi} + P_{wo}$$

$$P_{C3} = P_{db} + (P_{dt} + P_{lr}) + P_{hb} + P_{wo}$$

[1] In the event that simultaneous operation of motions is permitted, the appropriate combinations of impact loads shall be used.

$$P_{C4} = P_{db} + (P_{dt} + P_{lr}) + P_{ht} + P_{wo}$$

$$P_{C5} = P_{db} + P_{dt} + (P_p \text{ or } P_{tp})$$

*(b) Construction Loads*[1]

$$P_{C6} = P_{db} + (P_{dt} + P_{cn}) + P_{vi} + P_{wo}$$

$$P_{C7} = P_{db} + (P_{dt} + P_{cn}) + P_{hb} + P_{wo}$$

$$P_{C8} = P_{db} + (P_{dt} + P_{cn}) + P_{ht} + P_{wo}$$

*(c) Severe Environmental Loads*

$$P_{C9} = P_{db} + P_{dt} + P_{wd}$$

*(d) Extreme Environmental Loads*

$$P_{C10} = P_{db} + (P_{dt} + P_{cs}) + P_{es} + P_{wo}$$

$$P_{C11} = P_{db} + P_{dt} + P_{es} + P_{wo}$$

$$P_{C12} = P_{db} + (P_{dt} + P_{co}) + P_{eo} + P_{wo}$$

$$P_{C13} = P_{db} + P_{dt} + P_{eo} + P_{wo}$$

$$P_{C14} = P_{db} + P_{dt} + P_{wt}$$

*(e) Abnormal Event Loads*

$$P_{C15} = P_{db} + P_{dt} + P_a + P_{wo}$$

$$P_{C16} = P_{dt} + P_{db} + P_{lc} + P_{lh}$$

$$P_{C17} = P_{lc} + P_{tb}$$

## 4150 Seismic Analysis for Types I and II Cranes

**4151 Methods of Analysis.** A dynamic analysis shall be performed to establish the response of the crane to a seismic event. The type of analysis shall be a linear response spectrum; a linear response spectrum with consideration for the nonlinear aspects of friction, which would allow the trolley or bridge braked wheels to slide on their rails in their respective direction of travel; a linear time history; or a nonlinear time history. When the results indicate a slack rope condition, when handling a credible critical load, a nonlinear time history analysis shall be performed in accordance with para. 4154. For trolley or bridge sliding considerations, a minimum coefficient of friction of 0.3 shall be applied to the combined static plus dynamic braked wheel loads.

**4152 Seismic Input Data.** The seismic input data for the crane seismic analysis shall be provided in the specification for the crane. The seismic input shall be specified as broadened floor response spectra or time histories of acceleration, displacements, or velocities defined at an appropriate level in the structure supporting the crane.

For analysis of a crane with a suspended critical load, the specification for the crane shall provide the credible critical load. The basis for determining the credible critical load will be studies of site seismicity and expected crane usage (see para. 4132).

### 4153 Linear Analysis

**4153.1 Response Spectrum Method.** The crane shall be considered to respond as a linear elastic system when using the response spectrum method. The undamped natural modes and frequencies shall be computed using a model acceptable under the rules of this Section. These results shall serve as the basis for mode-by-mode computation of the response of the crane to each of the three components of seismic input.

**4153.2 Time-History Analysis.** Time histories of structural response at the appropriate level may be used for analysis of the crane. The time histories shall be provided by the purchaser, and shall account for parametric variation in the supporting structure. Procedures for assembling the mathematical model shall be in accordance with this Section. The effects of the three components of ground motion shall be combined in accordance with the following requirements.

*(a)* The representative maximum values of the structural responses to each of the three components of earthquake motion shall be combined by taking the square root of the sum of the squares of the maximum representative values of the codirectional responses caused by each of the three components of earthquake motion at a particular point of the structure or of the mathematical model.

*(b)* The maximum value of a particular response of interest for design of a given element may be obtained through a step-by-step method. The time-history responses from each of the three components of the earthquake motions may be obtained separately and then combined algebraically at each time step, or the response at each time step may be calculated directly, owing to the simultaneous action of the three components. The maximum response is determined by scanning the combined time-history solution. When this method is used, the earthquake motions specified in the three different directions shall be statistically independent.

**4153.3 Crane Mathematical Model**

*(a)* The crane shall be represented by a generalized three-dimensional system of nodes. The model's geometry shall reflect the overall size, length, connectivity, and stiffnesses of the various structural members. An appropriate element representation of each member shall be used to describe all components that contribute significantly to the stiffness of the crane. The elements shall include, but not necessarily be limited to, the following structural members: bridge girders, trolley frame, gantry legs, end ties, end trucks, platform supports, and cab supports; and for cranes required to be analyzed for credible critical loads, drum, upper block

**Fig. 4153.3-1 Typical Four-Wheel Trolley Model for Seismic Analysis**

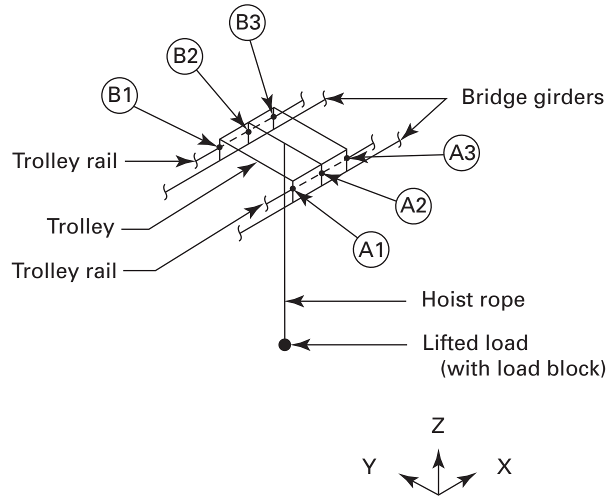
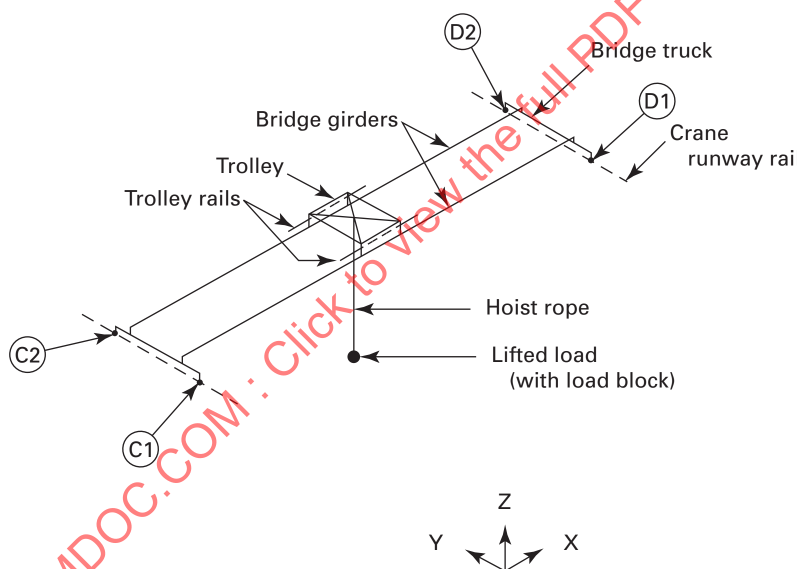



**Fig. 4153.3-2 Typical Four-Wheel Overhead Crane Model for Seismic Analysis**






supports, and hoist ropes. Line elements associated with the trolley and bridge trucks at the wheel locations shall be used to represent the connectivity of the trolley and bridge wheels to their respective rails, upon which the wheels roll. Typical four-wheel trolley and bridge models are shown in Figs. 4153.3-1 through 4153.3-4. Trolleys or bridges with more than four wheels shall be modeled with additional elements that represent components between the trolley or bridge structure and their respective rails. Additional elements may be employed to model boundary conditions as needed.

The loadings resulting from the pendulum motion of the lifted load are insignificant and need not be considered if the crane is not handling a load, the period of motion of the pendulum swing exceeds 3 sec, or the frequency of the pendulum swing is less than 20% of the fundamental horizontal frequencies of the crane.

NOTE: Typically, the horizontal displacement of the lifted load resulting from the pendulum swing is small, but in some cases this movement, combined with the movement of the trolley or bridge sliding on their respective rails, might result in load contact with the leg of a gantry crane, the facility's structure, or other plant equipment, and might require additional evaluation.

*(b)* For a trolley or bridge using bogie trucks, the trucks and their articulation shall be modeled in a manner that is representative of their structural characteristics. Where various connected structural members of the crane do not have intersecting centroidal axes, stiff line elements shall be used to represent the offset. These elements shall have stiffnesses that are an order of

Fig. 4153.3-3 Typical Four-Wheel Gantry Crane Model for Seismic Analysis

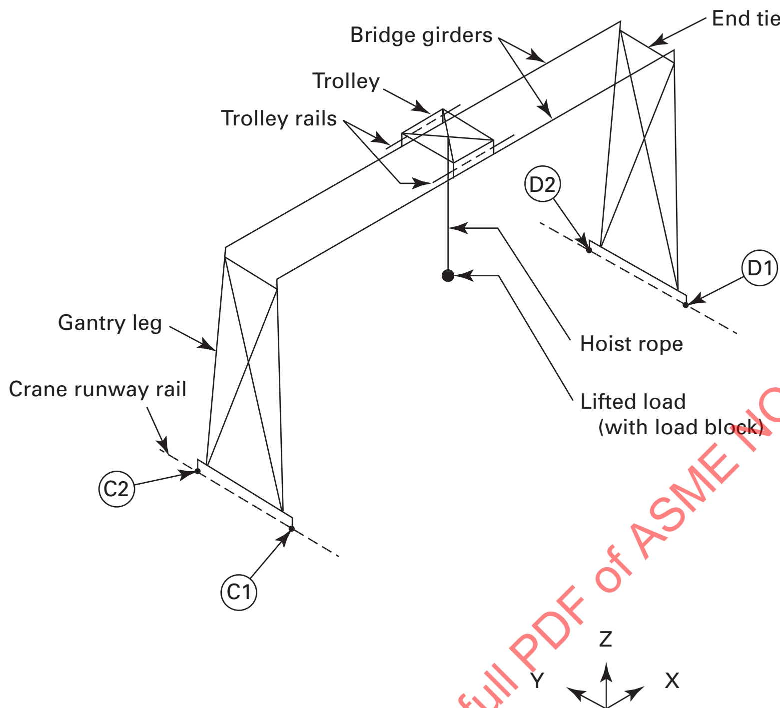
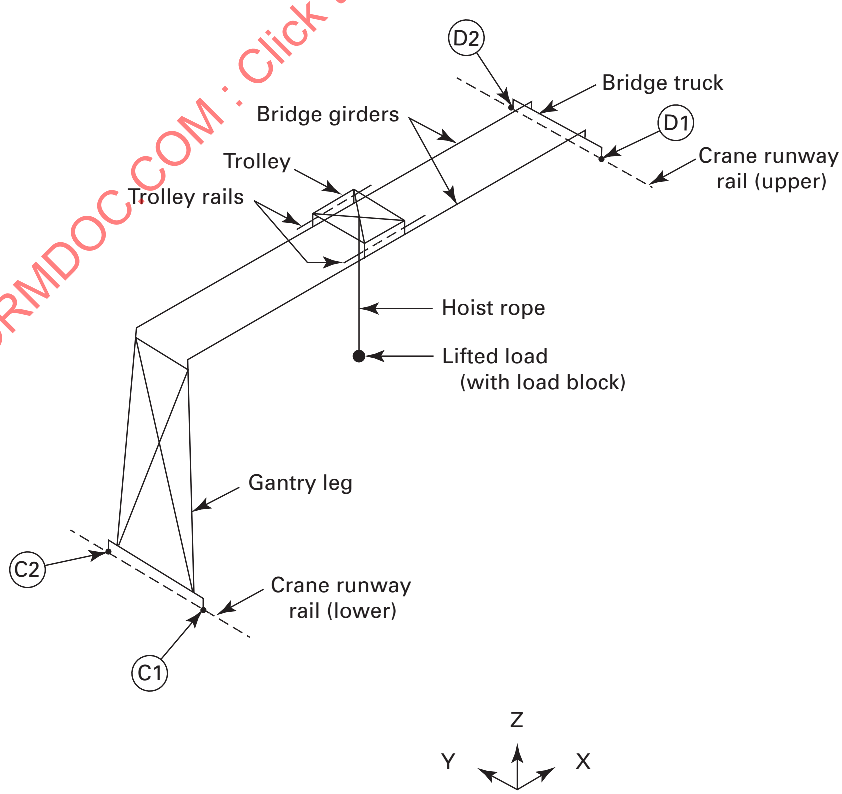





Fig. 4153.3-4 Typical Four-Wheel Semi-Gantry Crane Model for Seismic Analysis



magnitude higher than the most stiff structural member of the crane.

(c) A simplified finite element representation of the trolley structure using stiff line elements may be used for the crane dynamic model, provided it can be shown by rational analyses that the actual trolley structure responding as an uncoupled system has natural frequencies above 33 Hz. The simplified representation of the trolley structure shall be modeled in a manner that will not introduce an artificial stiffening effect between the two girders, but would allow for relative twist of the trolley structure between the two trolley trucks (i.e., the torsional stiffness of the trolley elements, connecting the two trolley trucks, should represent the torsional stiffness of the trolley structure). The model used for seismic analysis should be evaluated and revised if required to account for higher frequencies if plant operations induce such frequencies.

**4153.4 Location and Number of Dynamic Degrees of Freedom.** Dynamic degrees of freedom shall be assigned to a sufficient number of node points, and in such locations that the real mass and stiffness distribution of the crane are simulated. Structural members subject to concentrated loads shall be provided with additional nodes at the points where a concentrated load or its equivalent mass is positioned. Crane components to be modeled as mass points (concentrated loads) shall include, but not be limited to, upper and lower blocks, gear cases, motors, brakes, heavy electrical control cabinets, cab, wheel assemblies, and trunnion pins. The total number of masses, or degrees of freedom, selected shall be considered adequate when additional degrees of freedom do not result in more than a 10% increase in responses. Dynamic coupling shall be accounted for.

**4153.5 Decoupling Criteria for the Crane Runway.** The crane and runway shall be evaluated in each of the three orthogonal directions to determine if the crane can be represented as a separate model or a model coupled with the runway in each of the respective directions.

NOTE: Based on this evaluation, the crane model may be required to be coupled to the runway in only one or two of the three orthogonal directions.

For the crane to be considered decoupled from the runway, the criteria of (a) or (b) below shall be met.

(a) If $R_m < 0.01$, decoupling can be done for any $R_f$.

(b) If $0.01 \le R_m \le 0.1$, decoupling can be done if $R_f \le 0.8$ or if $R_f \ge 1.25$.

(c) If neither criteria (a) nor (b) is met, then an approximate model of the runway system shall be included with the crane model.

Mass ratio for the horizontal directions (X and Y)

$$R_m = \frac{\text{mass of the crane (without hoist load block or lifted load)}}{\text{mass of the runway system}}$$

Mass ratio for the vertical direction (Z)

$$R_m = \frac{\text{mass of the crane and lifted load}}{\text{mass of the runway system}}$$

Frequency ratio for each of the three independent orthogonal directions

$$R_f = \frac{\text{fundamental frequency of the crane}}{\text{frequency of the dominant runway motion}}$$

NOTE: The fundamental frequency of the crane is determined as being decoupled from the runway structure, and the frequency of the dominant runway motion is determined with consideration to the effective mass of the crane and lifted load.

The purchaser shall determine the mass and frequency characteristics of the crane runway systems in each of the three orthogonal directions.

**4153.6 Boundary Conditions at Trolley and Runway Rails.** The boundary conditions for the crane model shall be selected so that the resulting response, displacements, and forces in the crane structure are conservatively determined. Trolleys with four wheels shall be coupled to the bridge at the interface of the trolley wheels and trolley rails, as shown in Fig. 4153.3-1 and Table 4153.6-1 (unless restraining device requires additional coupling). Overhead, gantry, and semigantry cranes with four wheels shall be coupled to the crane runway rail at the interface of the bridge wheels and runway rails, as shown in Figs. 4153.3-2, 4153.3-3, and 4153.3-4, respectively, and Table 4153.6-2 (unless restraining device requires additional coupling). Trolleys or bridges with other than four wheels shall be coupled in a manner that is representative of the design being considered. For trolleys or bridges using bogie trucks, all wheels shall be coupled to their respective rails in the vertical (Z) direction, and the "braked" wheels coupled in the direction of truck travel (X direction for the trolley and Y direction for the bridge). If more than one wheel on a rail is "braked," only one wheel per rail shall be coupled to represent the "braked" wheels. For bogie truck assemblies that are guided by means either of reduced wheel float or by guide (side) rollers, both wheels shall be coupled to the rail, in the direction perpendicular to the rail (Y direction for the trolley and X direction for the bridge). When closely guided wheels are not used, or when the truck is guided by means of guide rollers at the center of the truck wheelbase, only the midpoint of the truck wheelbase is required to be coupled to the rail, in the direction perpendicular to the rail.

The crane bridge (including gantry legs, if applicable) and trolley shall be provided with restraint devices so that they remain on their respective runways during and after a seismic event. Characteristics of these devices that influence the dynamic behavior of the crane shall be included as boundary conditions in the model of the crane. The restraint devices shall be considered to be

### Table 4153.6-1 Boundary Conditions: Trolley Wheels to Trolley Rails

| | X Direction Options [Note (1)] | | Y Direction Options [Notes (2) and (3)] | | | | |
|---|---|---|---|---|---|---|---|
| Nodes | TX-1 | TX-2 | TY-1 | TY-2 | TY-3 | TY-4 | Z Direction |
| A1 | * | ~ | ~ | * | ~ | * | * |
| A2 | ~ | ~ | * | ~ | ~ | ~ | ~ |
| A3 | ~ | * | ~ | ~ | * | * | * |
| B1 | * | ~ | ~ | ~ | * | * | * |
| B2 | ~ | ~ | * | ~ | ~ | ~ | ~ |
| B3 | ~ | * | ~ | * | ~ | * | * |

GENERAL NOTES:
(a) The asterisk (*) indicates nodes that are coupled in direction shown, and the tilde (~) indicates nodes that are not coupled (free to translate).
(b) All nodes are to be considered free to rotate.

NOTES:
(1) Selection of coupled nodes in the X direction depends on the location of the braked wheels (couple only one wheel on each girder if more than one wheel on a rail is a braked wheel).
(2) For analysis, trolley coupling options TY-1, TY-2, or TY-3 are acceptable when the trolley is rigid, or is modeled as rigid, in the XY plane. When option TY-1 is used, the addition of fictitious rigid trolley and bridge line elements is required. These elements are only used for coupling in the Y direction. The X location of these elements is approximately at the X location of the trolley centroid.
(3) Option TY-4 should be used when the trolley is relatively flexible (and is modeled as such) in the XY plane (i.e., the diagonal distances of the trolley cross-corner nodes are allowed to change as a function of girder distortion and trolley stiffness).

### Table 4153.6-2 Boundary Conditions: Bridge Wheels to Crane Runway Rails

| | X Direction Options [Notes (1) and (2)] | | | | Y Direction Options [Notes (1) and (3)] | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nodes | BX-1 | BX-2 | BX-3 | BX-4 | BY-1 | BY-2 | BY-3 | BY-4 | Z Direction |
| C1 | * | * | ~ | * | * | ~ | * | ~ | * |
| C2 | * | * | * | ~ | ~ | * | ~ | * | * |
| D1 | * | ~ | ~ | * | * | ~ | ~ | * | * |
| D2 | * | ~ | * | ~ | ~ | * | * | ~ | * |

GENERAL NOTES:
(a) The asterisk (*) indicates nodes that are coupled in direction shown, and the tilde (~) indicates nodes that are not coupled (free to translate).
(b) All nodes are to be considered free to rotate.

NOTES:
(1) For polar cranes, the X and Y directions are defined as the directions perpendicular to and parallel with the tangent of the crane runway rail at the node location, respectively.
(2) Selection of the coupling option in the X direction depends on the type of crane being modeled, and if the crane is modeled as being coupled or decoupled from the crane runway system (para. 4153.5).

*(a)* Use option BX-1 for overhead cranes that are considered coupled to an approximate model of the crane runway system, and for both gantry cranes and semi-gantry cranes.

*(b)* Use option BX-2 for overhead cranes that are modeled as being decoupled from the crane runway system when the bridge lateral (X) displacement is held more tightly on one end of the bridge than the other end; this is normally the case when the crane runway on one end is more rigid in the lateral direction than the other end, or when the bridge wheels are guided more closely on one end of the bridge than the other end, normally by means of limited wheel float or the use of guide rollers.

*(c)* Use options BX-2, BX-3, or BX-4 for overhead cranes that are modeled as being decoupled from the crane runway system when the runway system and the bridge design on both ends are similar. When option BX-2 is used, couple the nodes on the end of the bridge that has the higher static load distribution.

(3) Selection of coupled nodes in the Y direction depends on the location of the braked wheels (couple only one wheel on each end of the bridge if more than one wheel on a rail is a braked wheel).

in contact with the resisting structure in establishing boundary conditions used in the analysis for the crane. Consideration for a restraining method (restraint device) shall be included in the model if appropriate.

The restraining device and the structure being restrained shall be designed for the maximum loads resulting from the applicable boundary condition. If the trolley (without additional restraining devices in the Y direction) is coupled to the bridge in the Y direction at only one location per girder, the corresponding resulting forces, determined by the computer analysis, shall be distributed to the two trolley wheels on the same rail, and each wheel shall be considered to transfer a minimum load equal to two-thirds of the total load. If the bridge is coupled to the runway in the X direction, at only one end of each girder with the bridge trucks not guided and both crane runway structural systems have similar horizontal stiffness characteristics, the resulting force corresponding to each girder, determined by the computer analysis, may be distributed to both ends of the bridge girder by an amount not less than a proportion based on the vertical bridge static reactions (ratio of the static bridge girder end reaction to the total static end reactions of the corresponding girder, mass distribution proportion), nor less than two-thirds of the total load.

**4153.7 Trolley Locations and Hoist Positions.** The crane shall be analyzed with the trolley located in different locations along the bridge, with and without a lifted load raised to different positions for each trolley location considered. The following describes the loading conditions to be used for this analysis:

*(a) Credible Critical Load on Hook.* This loading condition shall be analyzed with the hook at two different hoist positions. These hoist positions shall be specified by the owner and are the upper and lower hook positions that define the operating range of hook travel during the postulated seismic event. If the primary response of the crane is higher at some intermediate hook position, that hook position shall be analyzed, and the hook position that produces the lowest response (hook up or hook down position) need not be analyzed.

*(b) No Load on Hook.* For this loading condition, the hook (load block without load) shall be modeled as a mass at the end of the rope, with the hook raised to the up position.

For a typical crane that is similar in design on both ends of the bridge, three separate trolley positions shall be included in the analysis, which correspond to trolley located at its extreme end position of the trolley travel on the bridge (i.e., end hook approach); trolley located at the mid-span of the bridge; and trolley located at the quarter point of the trolley travel on the bridge. The mid-span trolley position is defined as the trolley position where the center of the hook/hoist rope, and the trolley wheel that is closest to the center of the hook (wheel that has the maximum static wheel load), are on opposite sides and equally distant from the center of the bridge span. The quarter point of the trolley travel is defined as the trolley position that is at the midpoint between the trolley at its end position and the trolley at its mid-span position.

If the crane is not similar on both ends of the bridge (e.g., semigantry cranes, and gantry cranes that have nonsimilar legs at each end of the bridge, or have girders that extend past the crane runway on only one end), then two additional trolley positions shall be analyzed, so that the trolley positioned at both of the extreme end positions and both of the quarter-point trolley positions are included in the overall analysis.

If the trolley at its end-of-travel position(s) is not closer to the bridge runway than one-fourth of the bridge span, then the analysis with the trolley at the quarter-point position(s) is not required.

If the crane arrangement is other than those described above (e.g., crane with multiple trolleys), the owner or purchaser shall specify the trolley(s) positions and loadings, and other applicable considerations that must be taken into account.

**4153.8 Damping Values.** The response of each mode shall be determined from the amplified response spectra for the appropriate values of structural damping. A damping value of 7% of critical damping shall be used for the crane when the SSE is used in the analysis. A damping value of 4% of critical damping shall be used when the OBE is used in the analysis.

**4153.9 Number of Modes Required for Seismic Analysis.** It is not generally necessary to include the contributions of all modes to the seismic response of the crane. A modal participation factor shall be used with the modal frequencies to select significant modes. Since high frequency modes may respond strongly in some cases, it is not sufficient to limit the modal analysis to the first several modes computed. Additional modes shall be computed until the inclusion of additional modes does not result in more than a 10% increase in response.

**4153.10 Combination of Modal Responses.** In combining the dynamic responses with the static and wind loadings (when applicable), as required in para. 4140(d), a sign convention shall be applied to the dynamic responses such that the combined results would yield the worst case for the loading condition being considered.

*(a) With No Closely Spaced Modes.* When the results of the modal dynamic analysis show that the crane modes are not closely spaced, the crane's response to each of the three components of seismic input shall be combined by taking the square root of the sum of the squares (SRSS).

*(b) With Closely Spaced Modes.* When the results of the modal dynamic analysis show that some or all of the modes are closely spaced (two consecutive modes are defined as closely spaced if their frequencies differ from each other by 10% or less of the lower frequency), modal responses for each of the three components for seismic input shall be combined using one of the following three methods.

*(1) Grouping Method.* Closely spaced modes shall be divided into groups that include all modes having frequencies between the lowest frequency in the group and a frequency 10% higher [see Note (1) below]. The representative maximum value of a particular response of interest for the design of a given element of a nuclear power plant structure, system, or the crane attributed to each such group of modes shall first be obtained by taking the sum of the absolute values of the corresponding peak values of the response of the element attributed to individual modes in that group. The representative maximum value of this particular response attributed to all the significant modes of the structure, system, or the crane shall then be obtained by taking the square root of the sum of the squares of corresponding representative maximum values of the response of the element attributed to each closely spaced group of modes and the remaining modal responses for the modes that are not closely spaced. Mathematically, this is expressed as follows:

$$R = \left[ \sum_{k=1}^{N} R_k^2 + \sum_{q=1}^{P} \sum_{l=i}^{j} \sum_{m=i}^{j} \left| R_{lq} R_{mq} \right| \right]^{1/2}$$

where $l \neq m$; $R_{lq}$ and $R_{mq}$ are modal responses, $R_l$ and $R_m$ within the $q$th group, respectively; $i$ is the number of the mode where a group starts; $j$ is the number of the mode where the group ends; $R$, $R_k$, and $N$ are as defined in Note (2) below; $P$ is the number of groups of closely spaced modes, excluding individual separated modes.

*(2) 10% Method*

$$R = \left[ \sum_{k=1}^{N} R_k^2 + 2\Sigma \left| R_i R_j \right| \right]^{1/2}$$

where $i \neq j$; and $R$, $R_k$, and $N$ are defined in Note (2) below. The second summation shall be done on all $i$ and $j$ modes whose frequencies are closely spaced to each other. Let $\omega_i$ and $\omega_j$ be the frequencies of the $i$th and $j$th modes. In order to verify which of the modes are closely spaced, the following equation shall be applied:

$$(\omega_j - \omega_i) \,/\, \omega_i \leq 0.1$$

Also,

$$1 \leq i < j \leq N$$

*(3) Double-Sum Method:*

$$R = \left[ \sum_{k=1}^{N} \sum_{s=1}^{N} \left| R_k R_s \right| \epsilon_{ks} \right]^{1/2}$$

where $R$, $R_k$, and $N$ are as defined in Note (2) below. $R_s$ is the peak value of the response of the element attributed to the $s$th mode, and $\epsilon_{ks}$ is a correlation coefficient between modes $k$ and $s$.

$$\epsilon_{ks} = \left\{ 1 + \left[ \frac{(\omega'_k - \omega'_s)}{(\beta'_k \omega_k + \beta'_s \omega_s)} \right]^2 \right\}^{-1}$$

in which

$$\omega'_k = \omega_k \left[ 1 - \beta_k^2 \right]^{1/2}$$

$$\beta'_k = \beta_k + 2 / (t_d\, \omega_k)$$

where $\omega_k$ and $\beta_k$ are the modal frequency and the damping ratio in the $k$th mode, respectively, and $t_d$ is the time duration of the earthquake.

NOTES:

(1) Groups shall be formed starting from the lowest frequency and working toward successively higher frequencies. No one frequency shall be in more than one group.

(2) $R$ is the representative maximum value of a particular response of a given element to a given component of an earthquake; $R_k$ is the peak value of the response of the element due to the $k$th mode; and $N$ is the number of significant modes considered in the modal response combination.

*(c) Combination of Three Orthogonal Components of Earthquake Motion.* The representative maximum values of the structural responses resulting from each of the three orthogonal components of the earthquake motion shall be combined at each node of the crane mathematical model by taking the square root of the sum of the squares (SRSS) in the following manner:

$$R_{\text{combined}} = (R_X^2 + R_Y^2 + R_Z^2)^{1/2}$$

where

$R_X$, $R_Y$, $R_Z$ = representative maximum values resulting from each of the three orthogonal components of the earthquake motion (X, Y, and Z, respectively)

$R_{\text{combined}}$ = total representative maximum value of the combined modal responses for the seismic event being considered (i.e., OBE or SSE)

$R_X$, $R_Y$, $R_Z$, and $R_{\text{combined}}$ represent the dynamic analytical results at each node (i.e., forces, moments, stresses, and displacements).

**4154 Nonlinear Time History for Slack Rope Condition.** For the case when the credible critical load is being supported by the hoist ropes, and the results of the linear analysis of para. 4153 indicate a slack rope condition, that is, rope going into compression, the nonlinear time-history method of analysis shall be used to determine the maximum rope tension loads resulting from a slack rope condition. These loads shall be used to verify rope compliance with design requirements. Also, these rope loads may be used as an alternate to the rope loads from the linear analysis results, in sizing of the hook, lower load block, upper sheave nest, hoist machinery components (gears, shafts, keys, couplings, etc.), or other components that are primarily affected only by the rope load and have no significant influence on the response.

Nonlinear analysis concerns the performance of a dynamic analysis of the crane, when subjected to earthquake-induced forces, taking into account the nonlinear properties (for example, tension only of the hoist ropes). To perform such an analysis, computer programs are available to solve the equations of motion via direct integration techniques at discrete time intervals over the time history of the earthquake.

**4154.1 Crane Mathematical Model.** The crane finite element model shall be similar to the one described in para. 4153.3 for the linear analysis, except that the crane trolley and bridge geometry may be simplified if justification can be provided that the coupling effects of those degrees of freedom that are omitted from the three-dimensional model are not significant. A nonlinear spring (tension member only) shall be used to represent the hoist ropes.

**4154.2 Location and Number of Dynamic Degrees of Freedom.** Dynamic degrees of freedom shall be assigned to a sufficient number of node points and in such locations that the real mass and stiffness distribution of the crane is simulated. An important consideration for modeling the crane for the nonlinear analysis is that the fundamental frequency of the crane system in its unloaded (no load on the hook) configuration approximates that determined by the linear analysis.

**4154.3 Boundary Conditions at Trolley and Runway Rails.** Boundary conditions for the crane model shall be consistent with those specified in para. 4153.6.

**4154.4 Trolley Locations and Hoist Positions.** A combined trolley and loaded hook position shall be selected so as to result in a crane system frequency that produces the severest slack rope conditions. Trolley locations and hoist positions specified in para. 4153.7 shall be considered.

**4154.5 Damping Values.** A critical damping ratio of 7% shall be used for the rope for determining the damping parameters required to form the damping matrix. Higher values may be used with adequate justification.

### 4160 Tolerances

Dimensions of welded beams, girders, and built-up members shall be within the tolerances specified by AWS D1.1. All measurements shall be based on 70°F ambient temperature and be taken at the manufacturer's plant prior to shipment, unless otherwise specified. A minimum dimensional check of a member will consider straightness, camber, lateral deviation of web to flange centerlines, and depth.

Overall crane dimensions shall be in accordance with the crane manufacturer's clearance drawing of the crane. Dimensions on the clearance drawings are the maximum dimensions of the crane and shall not be exceeded by the manufacturer. Height and end dimensions shall be shown in relationship to the top of the runway rail centerline. Cumulative measurements of crane components are permitted.

The accuracy of the runway rail dimensions shall be the responsibility of the purchaser. The runway rails shall be straight, parallel, level, and at the same elevation within the tolerances given in Fig. 4160-1. The crane manufacturer shall design the crane to operate properly within the runway rail tolerances given in Fig. 4160-1.

## 4200 MATERIALS AND CONNECTIONS

All materials of the structural components of the crane shall be an accepted type, suitable for the purpose for which the materials are to be used, and shall be in compliance with any additional requirements specified herein for the materials.

### 4210 Base Materials

#### 4211 Material

*(a)* The base materials listed in Table 4211-1 are considered acceptable for the structural components identified in para. 4400 of Types I and II cranes when they meet the requirements of para. 4212. The manufacturer shall report the materials actually employed to the purchaser. Other suitable materials, which are in compliance with the other provisions for materials specified herein, may be acceptable subject to approval by the purchaser.

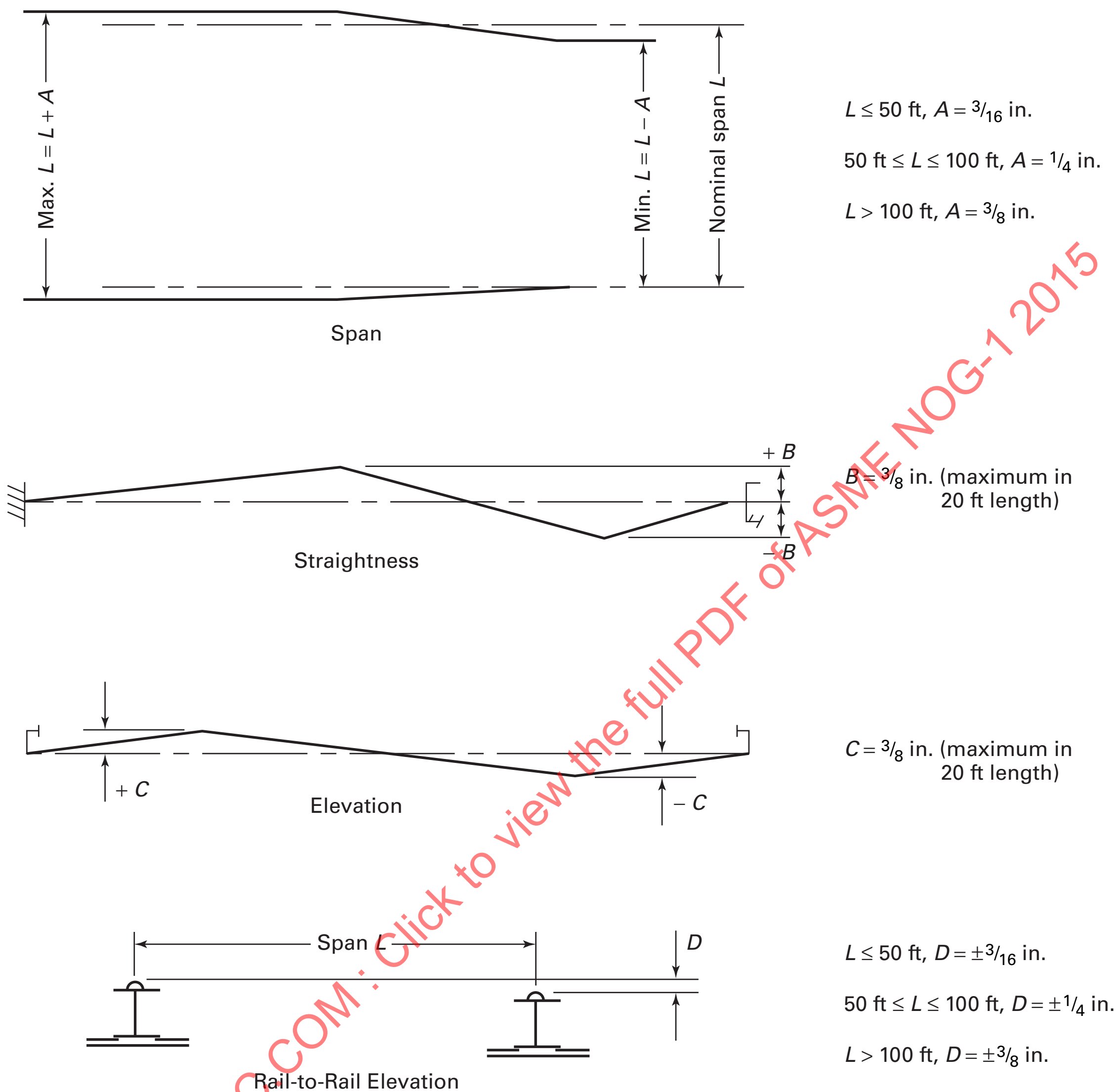
*(b)* The base materials for the components of cranes not included in (a) above shall be in accordance with specification CMAA 70.

#### 4212 Fracture Toughness

*(a)* Material for the structural components defined in para. 4211(a) for Types I and II cranes shall be impact tested in accordance with (a)(1) below, except as provided in (b) below. Materials for Type III cranes shall be in accordance with Specification CMAA 70. The purchaser shall specify the minimum operating temperature as defined in para. 1150.

*(1)* For material greater than $\frac{5}{8}$ in. thick, Charpy V-notch tests shall be performed in accordance with

**Fig. 4160-1 Runway Rail Alignment Tolerance**






(a)(3) below, or drop weight tested in accordance with (a)(2) below.

*(2)* The drop weight test shall be performed in accordance with ASTM E208 using specimen type P-1, P-2, or P-3. The sampling shall be in accordance with ASTM A20 when applicable or ASTM A673 frequency P except for the type of specimen. The specimen depth shall be at least as far from the material surface as that specified for tensile test specimens in the material specification. The nil-ductility transition temperature shall be a minimum of 30°F below the minimum operating temperature.

*(3)* The Charpy V-notch test shall be performed in accordance with ASTM A370 using full-size specimens if possible. For Type I cranes, the sampling shall be in accordance with ASTM A673 frequency P. For Type II cranes, the sampling shall be in accordance with ASTM A673 frequency H for specified minimum yields of 55 ksi or less, and frequency P for higher strength steels. The test temperature shall be a minimum of 30°F below the minimum operating temperature. The acceptance criteria shall be as shown in Table 4212-1. The results obtained with sub-size Charpy V-notch specimens shall be converted to full-size specimens in accordance with ASTM A673 Table 1 before comparison with the acceptance criteria.

*(b)* The base material shall be exempt from impact testing as required in (a) above provided one of the following is met:

*(1)* the nominal thickness is 5/8 in. or less

*(2)* the nominal cross-sectional area is 1 in.$^2$ or less

*(3)* the maximum tensile stress (including residual stresses if the component is not postweld heat treated)

## Table 4211-1 Acceptable Materials and Reference Properties for Structural Components

| ASTM Specification [Note (1)] | Grade or Class | Form | Size | Yield Strength, ksi | Tensile Strength, ksi |
|---|---|---|---|---|---|
| A36 | . . . | Plates, shapes, bars | Plates and bars ≤ 8 in.; see Note (2) for shapes | 36 min. | 58–80 |
| A53 | B | Pipe | Diameters ≤ 26 in. | 35 min. | 60 min. |
| A242 | . . . | Plates, shapes, bars | Plates and bars ≤ ¾ in., shapes with flange or leg thickness ≤ 1½ in. | 50 min. | 70 min. |
| | | | Plates and bars > ¾ in. and ≤ 1½ in., shapes with flange thickness > 1½ in. and ≤ 2 in. | 46 min. | 67 min. |
| | | | Plates and bars > 1½ in. and ≤ 4 in., shapes with flange thickness > 2 in. | 42 min. | 63 min. |
| A333 | 3, 7 | Pipe | Diameters ≤ 26 in. | 35 min. | 65 min. |
| | 4, 6 | | Diameters ≤ 26 in. | 35 min. | 60 min. |
| A500 | B | Rectangular tubing | Wall ≤ ⅝ in. and periphery ≤ 64 in. [Note (3)] | 46 min. | 58 min. |
| A501 | . . . | Tubing | Square and rectangular with sides ≤ 10 in. and wall ≤ 1 in., rounds ≤ 24 in. diameter and wall ≤ 1 in. | 36 min. | 58 min. |
| A516 | 65 | Plates | Thickness ≤ 8 in. | 35 min. | 65–85 |
| | 70 | | Thickness ≤ 8 in. | 38 min. | 70–90 |
| A537 | 1 | Plates | Thickness ≤ 2½ in. | 50 min. | 70–90 |
| | | | Thickness > 2½ in. and ≤ 4 in. | 45 min. | 65–85 |
| | 2 | | Thickness ≤ 2½ in. | 60 min. | 80–100 |
| | | | Thickness > 2½ in. and ≤ 4 in. | 55 min. | 75–95 |
| | | | Thickness > 4 in. and ≤ 6 in. | 46 min. | 70–90 |
| | 3 | | Thickness ≤ 2½ in. | 55 min. | 80–100 |
| | | | Thickness > 2½ in. and ≤ 4 in. | 50 min. | 75–95 |
| | | | Thickness > 4 in. and ≤ 6 in. | 40 min. | 70–90 |
| A572 | 42 | Plates, shapes, bars | Plates and bars ≤ 6 in.; and shapes | 42 min. | 60 min. |
| | 50 | | Plates and bars ≤ 4 in.; and shapes | 50 min. | 65 min. |
| | 55 | | Plates and bars ≤ 2 in.; and shapes | 55 min. | 70 min. |
| | 60 | | Plates and bars ≤ 1¼ in., shapes with flange or leg thickness ≤ 2 in. | 60 min. | 75 min. |
| | 65 | | Plates and bars ≤ 1¼ in., shapes with flange or leg thickness ≤ 2 in. | 65 min. | 80 min. |
| A588 | . . . | Plates, shapes, bars | Plates and bars ≤ 4 in.; and shapes | 50 min. | 70 min. |
| | | | Plates and bars > 4 in. and ≤ 5 in. | 46 min. | 67 min. |
| | | | Plates and bars > 5 in. and ≤ 8 in. | 42 min. | 63 min. |
| A618 | Ia, Ib, II | Tubing | Wall ≤ ¾ in. | 50 min. | 70 min. |
| | | | Wall > ¾ in. and ≤ 1½ in. | 46 min. | 67 min. |
| | III | | All tubing | 50 min. | 65 min. |
| A633 | A | Plates | Thickness ≤ 4 in. | 42 min. | 63–83 |
| | C, D | | Thickness ≤ 2½ in. | 50 min. | 70–90 |
| | | | Thickness > 2½ in. and ≤ 4 in. | 46 min. | 65–85 |
| | E | | Thickness ≤ 4 in. | 60 min. | 80–100 |
| | | | Thickness > 4 in. and ≤ 6 in. | 55 min. | 75–95 |
| A709 | 36 | Plates, shapes, bars | Plates and bars ≤ 4 in., and shapes [Note (2)] | 36 min. | 58–80 |
| | 50 | | Plates and bars ≤ 4 in., and shapes | 50 min. | 65 min. |
| | 50W | | Plates and bars ≤ 4 in., and shapes | 50 min. | 70 min. |
| A737 | B | Plates | Thickness ≤ 2½ in. | 50 min. | 70–90 |
| | C | | Thickness ≤ 2½ in. | 60 min. | 80–100 |
| A913 | 50 | Shapes | All shapes | 50 min. | 65 min. |
| | 60 | | All shapes | 60 min. | 75 min. |
| | 65 | | All shapes | 65 min. | 80 min. |
| | 70 | | All shapes | 70 min. | 90 min. |
| A992 | . . . | Shapes | All shapes [Note (4)] | 50–65 | 65 min. |

GENERAL NOTE: The above data was obtained from the ASTM 2007 publication.

NOTES:

(1) For additional material information, see the referenced ASTM specification.

(2) For wide flange shapes with flange thickness over 3 in., the 80 ksi maximum tensile strength does not apply.

(3) The exceptions from Fracture Toughness requirements in para. 4212 do not apply to this material.

(4) The yield strength to tensile strength ratio shall not exceed 0.85.

**Table 4212-1 Required $C_v$ Energy Values for Structural Materials (Except Bolting) [Extracted from Table ND-2311(a)-1, Section III, Division 1, 1980 Edition, ASME Boiler and Pressure Vessel Code]**

| | Energy, ft-lb, for Materials of Specified Minimum Yield Strength, ksi | | | | | |
|---|---|---|---|---|---|---|
| | 40 or Less | | Over 40 to 55, Incl. | | Over 55 to 105, Incl. | |
| Nominal Thickness, in. | Average of 3 | Lowest of 3 | Average of 3 | Lowest of 3 | Average of 3 | Lowest of 3 |
| Over $^5/_8$ to $^3/_4$, incl. | 13 | 10 | 15 | 10 | 20 | 15 |
| Over $^3/_4$ to 1, incl. | 15 | 10 | 20 | 15 | 25 | 20 |
| Over 1 to $1^1/_2$, incl. | 20 | 15 | 25 | 20 | 30 | 25 |
| Over $1^1/_2$ to $2^1/_2$, incl. | 25 | 20 | 35 | 30 | 40 | 35 |
| Over $2^1/_2$ | 30 | 25 | 40 | 35 | 45 | 40 |

**Table 4221-1 Acceptable Fastener Materials for Structural Connections for Types I and II Cranes**

| ASTM Specification [Note (1)] | Grade, Class, or Type | Size, in. | Min. Proof Load Stress, ksi | Min. Yield Strength, ksi | Tensile Strength, ksi |
|---|---|---|---|---|---|
| A193 | B7 | ≤ $2^1/_2$ | . . . | 105 | 125 min. |
| | | > $2^1/_2$ and ≤ 4 | . . . | 95 | 115 min. |
| | | > 4 and ≤ 7 | . . . | 75 | 100 min. |
| | B16 | ≤ $2^1/_2$ | . . . | 105 | 125 min. |
| | | > $2^1/_2$ and ≤ 4 | . . . | 95 | 110 min. |
| | | > 4 and ≤ 8 | . . . | 85 | 100 min. |
| A320 | L7 | ≤ $2^1/_2$ | . . . | 105 | 125 min. |
| | L43 | ≤ 4 | . . . | 105 | 125 min. |
| A325 | 1 and 3 | ≥ $^1/_2$ and ≤ 1 | 85 | 92 | 120 min. |
| | | ≥ $1^1/_8$ and ≤ $1^1/_2$ | 74 | 81 | 105 min. |
| A490 | 1 and 3 | ≥ $^1/_2$ and ≤ $1^1/_2$ | 120 | 130 | 150–173 |

GENERAL NOTE: The above data was obtained from the ASTM 2007 publication.

NOTE:
(1) For additional information, and requirements for nuts and washers, see the referenced ASTM specification.



under all conditions of loading required in para. 4100 does not exceed 6,000 psi

*(4)* the component is fabricated from an austenitic stainless steel or a nonferrous material not subject to a ductile brittle transition

*(5)* the component is fabricated from normalized ASTM A516 Grade 70 steel and the required test temperature or the lowest service temperature is greater than 0°F

*(6)* the component is fabricated from normalized ASTM A537 Class 1 steel and the required test temperature or the lowest service temperature is greater than −30°F

## 4220 Fastener Materials

### 4221 Material

*(a)* The fastener materials in Table 4221-1 are considered acceptable for the structural interconnections of Types I and II cranes. The manufacturer shall report the materials actually employed to the purchaser.

*(b)* The fastener materials for structural components of cranes not included in (a) above shall be in accordance with CMAA 70.

*(c)* When not restricted by para. 1145, the fastener materials in Table 4221-2 may be galvanized or coated with zinc-rich paints. Fastener materials with a hardness higher than 320 BHN shall not be galvanized.

*(d)* The fastener finish and tolerances shall be suitable for the type of connection in which it is employed.

### 4222 Fracture Toughness

*(a)* Fastener materials for connections defined in 4221(a) shall be impact tested in accordance with (a)(1) below except as provided in (b) below. The purchaser shall provide the minimum operating temperature as defined in para. 1150.

**Table 4221-2 Fastener Materials That May Be Galvanized**

| | |
|---|---|
| ASTM A307 | . . . |
| ASTM A325 | Type 1 |
| ASTM A449 | . . . |
| ASTM A563 | Grade DH |
| ASTM A194 | Grade 2H |

**Table 4222-1 $C_v$ Energy Values for Fastener Materials**

| Nominal Diameter, in. | Energy, ft-lb, for Materials of Specified Minimum Yield Strength, ksi [Note (1)] | | | | | |
|---|---|---|---|---|---|---|
| | 55 or Less | | Over 55 to 105, Incl. [Note (2)] | | Over 105 to 145, Incl. | |
| | Average of 3 | Lowest of 3 | Average of 3 | Lowest of 3 | Average of 3 | Lowest of 3 |
| Over 1 to 2½ | 25 | 20 | 30 | 25 | 35 | 30 |
| Over 2½ to 4 | 30 | 25 | 35 | 30 | 40 | 35 |
| Over 4 | 35 | 30 | 40 | 35 | 45 | 40 |

GENERAL NOTE: For restrictions on the use of subsize specimens, see para. 4212(a)(3).

NOTES:

(1) When a minimum yield strength is not a part of the material specification, the actual yield strength shall be determined per ASTM A370 and used to determine the required energy.

(2) Stock fasteners having an average energy of 20 ft-lb and a minimum energy of 15 ft-lb at −150°F may be used for minimum operating temperatures above −90°F without additional testing.



*(1)* Charpy V-notch tests shall be performed in accordance with ASTM A370. For bolts and studs, the sampling shall be in accordance with ASTM A320. For nuts, the sampling shall be in accordance with ASTM A194. The test temperature shall be equal to or less than 30°F below the minimum operating temperature as defined above. The acceptance criteria shall be as shown in Table 4222-1.

*(b)* Fastener materials shall be exempt from impact testing as required in (a) above, provided the nominal size of the bolt or stud is 1 in. or less.

## 4230 Welding Materials

**4231 Material.** All welding materials shall be in compliance with the requirements of AWS D1.1 and the additional requirements specified herein.

*(a)* Matching filler metal of adequate toughness per para. 4232 shall be used. For the shielded metal arc welding (SMAW) process, low hydrogen type electrodes shall be used for the structural connections of Types I and II cranes per para. 4400.

*(b)* The filler metal for the structural connections of cranes not included in (a) above shall be as specified.

*(c)* If the SMAW process is employed for connections per (b) above but one of the base metals is on a component per para. 4211(a) that is over 2½ in. thick, and is subject to applied tensile stresses in excess of 6,000 psi, low hydrogen type electrodes shall be used.

**Table 4232-1 Test Temperature for Filler Metal — Charpy V-Notch Impact Tests With 20 ft-lb Average Energy**

| Specified Minimum Tensile Strength, ksi | °F Below Minimum Operating Temperature |
|---|---|
| 75 or less | 30 |
| 75 to 95, incl. | 50 |
| Over 95 | 70 |

### 4232 Fracture Toughness

*(a)* The filler metal defined in para. 4231(a) shall be impact tested in accordance with (a)(1) below except as provided in (b) below. The purchaser shall provide the minimum operating temperature as defined in para. 1150.

*(1)* Charpy V-notch tests shall be performed in accordance with the filler metal specification. The difference between the minimum operating temperature and the test temperature shall be in accordance with Table 4232-1.

*(b)* The filler metal shall be exempt from impact testing as required in (a) above, provided

*(1)* the base materials are exempt per paras. 4212(b)(1), (2), (3), or (4), or

*(2)* the effective throat of the nominal weld is $\frac{5}{8}$ in. or less

### 4240 Welded Studs

Welded studs shall not be employed for the connections of the structural components defined in para. 4400. Studs welded to the structural components of the crane shall comply with the requirements for studs specified in AWS D1.1, and shall be compatible with the base material.

### 4250 Connections

**4251 Welded Connections.** Welded connections shall comply with the requirements of AWS D1.1 except as specified herein.

**4251.1 Welding Procedures.** All welds for Types I and II cranes shall be performed in accordance with written procedures that establish limitations of variables consistent with AWS D1.1. These welds may be either prequalified or qualified in accordance with AWS D1.1.

**4251.2 Qualification Impact Tests.** The weld procedure qualification shall be exempt from impact testing as required per Mandatory Appendix I, para. I-4251.2, provided one of the following is met:

*(a)* the base materials are exempt per para. 4212(b); or

*(b)* the base materials are in Material Group 1 of Table 3.1 of AWS D1.1, the weld is made by shielded metal arc welding, submerged arc welding, gas metal arc welding, or flux cored arc welding, and the filler metal is exempt per para. 4232(b); or

*(c)* the base materials are in Material Group 1 of Table 3.1 of AWS D1.1, the weld is made by shielded metal arc welding, submerged arc welding, gas metal arc welding, or flux cored arc welding, and the weld is postweld heat treated per para. 4251.5.

**4251.3 Combination of Weld Types.** If two or more of the general types of welds (groove, fillet, plug, slot) are combined in a single joint, the allowable capacity of each shall be separately computed with reference to the axis of the group in order to determine the allowable capacity of the combination.

**4251.4 Nondestructive Examination Requirements.** All welds shall be visually inspected over their entire lengths. Additional inspection and testing of the joints of the three types of cranes shall be as stated below. Examination and acceptance criteria of welds and repairs shall be in accordance with AWS D1.1 unless otherwise stated below.

*(a) Types I and II Cranes.* The following inspections and tests shall be applied to welded structural connections. Percents of welds specified for inspection are measured along each face. This doubles the length for fillet welds on both sides of a joint. The length subject to examination of other welds shall be considered as doubled when welds are made from both sides. Areas examined shall be randomly distributed along the weld length.

*(1)* Full penetration butt welds: 100% volumetric examination by either radiographic or ultrasonic testing unless the specification for the crane stipulates which method to use.

*(2)* Other welds with an effective throat over $\frac{3}{8}$ in.: dye penetrant or magnetic particle testing as follows unless the specification for the crane stipulates which method to use:

*(-a)* 100% of each of trolley load girt welds

*(-b)* 10% of each of the cover plate or flange to web welds of crane girders

*(3)* Other welds as stipulated in the crane specification.

*(4) Lamellar Tearing*

*(a)* Weld joints shall be designed to minimize base material strain in the through-thickness direction due to weld shrinkage.

*(b)* When base materials are subject to weld shrinkage strains in the through-thickness direction in highly restrained joints (typically thick sections utilized in tee and corner joints), the base materials shall be ultrasonically tested in accordance with Mandatory Appendix I, para. I-4251.4.

*(b) Type III Cranes.* Nondestructive examination requirements for welds and base metal shall be in accordance with CMAA 70 and the manufacturer's standards unless otherwise stated in the specification for the crane.

**4251.5 Postweld Heat Treatment**

*(a) Types I and II Cranes.* Welded connections shall be postweld heat treated (stress relieved) in accordance with AWS D1.1 except where exempted by Table 4251.5-1. However, exempted material may be

**Table 4251.5-1 Exemptions to Mandatory Postweld Heat Treatment**

| Material Class [Note (1)] | Effective Throat of Weld, in. — Not Toughness Tested [Note (2)] | Effective Throat of Weld, in. — Toughness Tested [Notes (2) and (3)] |
|---|---|---|
| I | $1\frac{1}{2}$ or less | 4 or less |
| II | $1\frac{1}{2}$ or less | 4 or less |
| III | $1\frac{1}{2}$ or less | 4 or less |

NOTES:

(1) Groups are per Table 3.1 of AWS D1.1. Carbon and low alloy steels not in this Table shall be exempt from postweld heat treatment for thicknesses of $\frac{1}{2}$ in. or less, provided the carbon does not exceed 0.35%.

(2) The manufacturer may test materials or procedures otherwise exempted from toughness testing in order to apply this exemption to postweld heat treating.

(3) Materials qualified by testing to para. 4212. Weld procedures qualified by testing to para. 4251.2.

postweld heat treated at the manufacturer's option. Times and temperatures per AWS D1.1 shall be employed.

When it is not practical to postweld heat treat an entire assembly, local postweld heat treatment shall be employed. Local postweld heat treatment shall be accomplished by heating a band of metal that includes the joint. Heating may be obtained by any method that will ensure sufficient uniformity without harming the material. The width of the heated band on each side of the greatest width of the finished weld shall be at least twice the effective throat of the weld. The material outside the heated band shall be protected to avoid harmful temperature gradients.

When postweld heat treating is employed, the following shall be observed.

*(1)* All required postweld heat treating shall be covered by a written procedure.

*(2)* Localized postweld heat treating may be employed as stated above, when approved by the design engineer. A written procedure must address the same seven points outlined in (a)(3) below for furnace postweld heat treating.

*(3)* For furnace postweld heat treating, the procedure must address the following:

*(-a)* temperature at start of thermal cycle

*(-b)* rate of heating

*(-c)* maximum allowable variation of temperature throughout the portion of the part being treated

*(-d)* maximum temperature tolerance at stress relief temperature

*(-e)* holding time at stress relief temperature

*(-f)* rate of cooling to temperature suitable for removal of work from the furnace

*(-g)* location of thermocouples and the number required

Vibratory conditioning to improve dimensional stability may be used at the option of the Manufacturer. The conditioning shall be done in accordance with the recommendations and procedures established by the manufacturer of the equipment.

*(b) Type III Cranes.* The manufacturer shall determine the need for postweld heat treatment. When used, PWHT shall comply with AWS D1.1.

**4251.6 Stud Welding.** The welding of studs shall be in accordance with AWS D1.1. The thickness of the base material to which studs are welded shall equal or exceed 20% of the nominal stud diameter to minimize burn-through.

#### 4252 Bolted Connections

**4252.1 Structural Joints Using ASTM A325 or ASTM A490 Bolts.** Structural joints for structural components identified under para. 4400 using ASTM A325 or ASTM A490 bolts shall be designed and installed in accordance with the AISC "Specification for Structural Joints Using ASTM A325 or A490 Bolts." Bolt holes shall be subpunched and reamed or drilled. Standard holes shall have a diameter nominally $^1\!/_{16}$ in. in excess of the nominal bolt diameter. Slotted bolt holes shall not be used except for connections that may require field adjustment for fitting the crane to the runway.

**4252.2 Structural Joints Using Bolts Other Than ASTM A325 or ASTM A490.** Structural joints using bolts other than ASTM A325 or ASTM A490 shall be bearing type and shall comply with the requirements for non-high-strength bolts specified in the AISC "Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design." All bolts shall be torqued to a pretension load on the bolt of 60% to 70% of the minimum yield strength of the bolt material. Standard holes shall have a diameter nominally $^1\!/_{16}$ in. in excess of the nominal bolt diameter, except for bound bolts.

**4252.3 Pitch and Edge Distances.** The minimum pitch between centers of bolt holes and minimum edge distances from the center of a bolt hole to any edge shall be as stipulated in the AISC "Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design."

**4252.4 Bolt Identification.** The bolting of the structural joints of the Types I and II cranes shall be identifiable. A unique marking system shall be used to identify type and/or grade of bolts and nuts used.

**4253 Field Connections.** All field connections of structural components shall be bolted unless otherwise approved by the purchaser. The manufacturer shall provide sufficient information on drawings or in installation manuals on the requirements for all field connections.

## 4300 DESIGN CRITERIA

### 4310 Basic Allowable Stresses for Structural Steel Members

**4311 Members Not Controlled by Buckling.** For members not controlled by buckling, the basic allowable stresses in structural steel members of the crane shall not exceed values in Table 4311-1.

**4312 Compression Members Controlled by Buckling.** For compression members with an equivalent slenderness ratio

$$\frac{kl}{r} < C_c = \sqrt{\frac{2\pi^2 E}{\sigma_y}}$$

where

$E$ = modulus of elasticity

$\sigma_y$ = yield point

**Table 4311-1 Maximum Allowable Stresses in Structural Steel Members**

| | Stress Type (All Expressed in Terms of $\sigma_y$) | | | |
|---|---|---|---|---|
| Loading Condition | Tension | Compression [Note (1)] | Shear | Bearing |
| Operating | 0.50 | 0.50 | 0.4 | CMAA 70 |
| Construction | 0.50 | 0.50 | 0.4 | CMAA 70 |
| Severe environmental | 0.67 | 0.67 | 0.45 | . . . |
| Extreme environmental | 0.90 | 0.90 | 0.5 | . . . |

NOTE:
(1) For gross section.

The allowable axial compression stress shall not exceed the value

$$\sigma_a = \left[1 - (kl/r)^2/2C_c^2\right](\sigma_y/DF)$$

where
$DF$ = design factor
$k$ = effective length factor
$l$ = length of compression member
$r$ = radius of gyration of member

The required design factor shall be equal to:

$$DF = N\left[\frac{5}{3} + \frac{3}{8}\left(\frac{\frac{kl}{r}}{C_c}\right) - \frac{1}{8}\left(\frac{\frac{kl}{r}}{C_c}\right)^3\right]$$

Value of $N$ for each loading condition is: operating, 1.2; construction, 1.2; severe environmental, 0.9; extreme environmental, 0.67. For compression members with an equivalent slenderness ratio

$$kl/r > C_c$$

the allowable axial compression stress shall not exceed the value

$$\sigma_a = \frac{12\pi^2 E}{23N\left(\frac{kl}{r}\right)^2}$$

In lieu of calculating the allowable stress by formula, the allowable stress listed in AISC divided by $N$ may be used.

**4313 Bending Stress.** The allowable bending stress for members other than those girders conforming to the dimensional criteria outlined in para. 4333 shall conform to AISC "Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design" Chapter F divided by 1.12$N$ for the different loading conditions.

**4314 Welds.** Basic allowable stresses in welds shall be as specified in AWS D1.1. Allowable stresses for all types of welds may be increased for severe environmental load combinations by a factor of 1.33, and for extreme environmental load combinations by a factor of 1.50.

**Table 4315-1 Allowable Stresses for Bolts Other Than ASTM A325 or ASTM A490**

| | Stress Type (Expressed in Terms of Ultimate Strength) | |
|---|---|---|
| Loading Condition | Tension | Shear |
| Operating | 0.33 | 0.17 |
| Construction | 0.33 | 0.17 |
| Severe environmental | 0.44 | 0.23 |
| Extreme environmental | 0.50 | 0.26 |

**4315 Bolts**

(a) *ASTM A325 or ASTM A490 Bolts.* Allowable working stresses for operational or construction loads shall be in accordance with AISC "Specification for Structural Joints Using ASTM A325 or A490 Bolts." Allowable working stresses for other loadings shall be as follows.

(1) *Bearing-Type Joints.* Allowable working stresses for bearing-type joints may be increased by a factor of 1.33 for severe environmental loadings, and by a factor of 1.50 for extreme environmental loadings.

(2) *Friction-Type Joints.* Allowable working stresses for friction-type joints may not be increased for severe or extreme environmental loadings.

(b) *Bolts Other Than ASTM A325 or ASTM A490.* Allowable stresses shall be in accordance with Table 4315-1.

## 4320 Combined Stresses

**4321 Axial Compression and Bending.** Members subjected to both axial compression and bending stresses shall satisfy the following requirements:

$$\frac{\sigma}{\sigma_a} + \frac{C_{mx}\sigma_{bx}}{\left(1 - \frac{\sigma}{\sigma'_{ex}}\right)\sigma_{abx}} + \frac{C_{my}\sigma_{by}}{\left(1 - \frac{\sigma}{\sigma'_{ey}}\right)\sigma_{aby}} \le 1.0 \qquad (1)$$

$$\frac{\sigma}{\sigma_{ac}} + \frac{\sigma_{bx}}{\sigma_{abx}} + \frac{\sigma_{by}}{\sigma_{aby}} \le 1.0 \qquad (2)$$

where

$C_m$ = a coefficient whose value shall be as given in (a), (b), and (c) below
$\sigma$ = computed axial stress
$\sigma_b$ = computed compressive bending stress at the point under consideration

When $\sigma/\sigma_a \leq 0.15$, the following equation may be used in lieu of the above equations:

$$\frac{\sigma}{\sigma_a} + \frac{\sigma_{bx}}{\sigma_{abx}} + \frac{\sigma_{by}}{\sigma_{aby}} \leq 1.0 \qquad (3)$$

In eqs. (1), (2), and (3), the subscripts $x$ and $y$, combined with subscripts $b$, $m$, and $e$, indicate the axis of bending about which a particular stress or design property applies; and $\sigma_a$ and $\sigma_{ab}$ are the allowable axial and bending stresses, respectively. (See paras. 4311 and 4312. Note that $\sigma_a = \sigma_{ab}$ in paras. 4311 and 4312; $\sigma_{ac} = \sigma_a$ as given in para. 4311 only.)

$$\sigma'_e = \frac{12\pi^2 E}{23N\left(\frac{kl}{r}\right)^2} \qquad (4)$$

where

$k$ = effective length factor in the plane of bending
$l$ = actual unbraced length in the plane of bending
$N$ = loading condition factor given in para. 4312
$r$ = corresponding radius of gyration

*(a)* For compression members in frames subject to joint translation, $C_m = 0.85$.

*(b)* For restrained compression members in frames braced against joint translation and not subject to transverse loading between their supports in the plane of bending

$$C_m = 0.6 - 0.4\left(\frac{M_1}{M_2}\right) \text{ but not less than } 0.4$$

where $M_1/M_2$ is the ratio of the smaller to larger moments at the ends of that portion of the member unbraced in the plane of bending under consideration. $M_1/M_2$ is positive when the member is bent in reverse curvature and negative when it is bent in a single curvature.

*(c)* For compression members in frames braced against joint translation in the plane of loading and subjected to transverse loading between their supports, the value of $C_m$ may be determined by rational analysis; however, in lieu of such analysis, the following values may be used:

*(1)* For members whose ends are restrained, $C_m = 0.85$.

*(2)* For members whose ends are unrestrained, $C_m = 1.0$.

**4322 Axial Tension and Bending.** Members subject to both axial tension and bending stresses shall satisfy the requirements of eq. (3). The computed bending tensile stress, taken alone, shall not exceed the applicable value according to para. 4311.

**4323 Shear and Tension**

*(a)* Bolts subject to combined shear and tension shall be so proportional that the tension stress, psi, produced by forces applied to the connected parts, shall not exceed the following.

*(1)* For A325 bolts in bearing-type joints

$$\sigma_{at} = 55{,}000R - 1.8\tau \leq 44{,}000R$$

*(2)* For A490 bolts in bearing-type joints

$$\sigma_{at} = 68{,}000R - 1.8\tau \leq 54{,}000R$$

*(3)* For other bolting materials in bearing-type joints

$$\sigma_{at} = 0.6\sigma_y R - 1.6\tau$$

where $\tau$ (the shear stress produced by the same forces) shall not exceed the value for the shear given in para. 4315. $\sigma_y$ is the yield stress (the proof stress may be used). $R$ is given as follows:

*(-a)* operating conditions: $R = 1$

*(-b)* construction conditions: $R = 1$

*(-c)* severe environmental conditions: $R = 1.33$

*(-d)* extreme environmental conditions: $R = 1.50$

*(b)* For bolts used in friction-type joints, the shear stress allowed in para. 4315 shall be reduced so that:

*(1)* for A325 bolts

$$\tau_a = 15{,}000\,(1 - \sigma_t A_b/T_b)$$

*(2)* for A490 bolts

$$\tau_a = 20{,}000\,(1 - \sigma_t A_b/T_b)$$

where

$A_b$ = tensile stress area
$T_b$ = specified pretension load of the bolt
$\sigma_t$ = average tensile stress due to a direct load applied to all of the bolts in a connection

In friction-type joints, the allowable shear stress may not be increased due to environmental conditions.

**4324 Shear and Bending.** The maximum combined shear stress due to shear, bending, and direct stresses shall not exceed the allowable values for shear as given in para. 4311, except that in severe and extreme environmental conditions, the allowable shear stress may be increased by 20%.

## 4330 Buckling

**4331 Local Buckling or Crippling of Flat Plates.** The structural design of the crane must guard against local buckling of plates such as webs and cover plates of girders, etc., by limiting the allowable compression stress along opposite edges and the uniformly distributed shear stress assumed to be acting around all edges of the plate or a combination of both.

The critical buckling stress, $\sigma_{cr}$, shall be assumed to be a multiple of the Euler stress, $\sigma_e$

$$\sigma_e = \frac{\pi^2 E}{12(1 - \mu^2)}\left(\frac{t}{b}\right)^2$$

where

- $b$ = plate width measured in the direction perpendicular to the compression force
- $E$ = modulus of elasticity in compression (for steel, 29,000,000 psi)
- $t$ = thickness of plate, in.
- $\mu$ = Poisson's ratio (for steel, 0.3)

The critical buckling stress in the elastic range

$$\frac{b/t}{\sqrt{K}} \geq \sqrt{\frac{\pi^2 E}{12\,(1 - \mu^2)\,0.7576\sigma_y}} \qquad (5)$$

where

- $K$ = buckling coefficient (Table 4332.1-1)
- = $K_\sigma$ for compression
- = $K_\tau$ for shear

For carbon steel

$$\frac{b/t}{\sqrt{K}} \geq \sqrt{\frac{2.62 \times 10^7}{0.7576\sigma_y}} \qquad (6)$$

For A36 steel

$$\frac{b/t}{\sqrt{K}} \geq 30.99$$

shall be assumed to be

$$\sigma_{cr} = \sigma_e K_\sigma \text{ (for compression)}$$

$$\tau_{cr} = \sigma_e \frac{K_\tau}{\sqrt{3}} \text{ (for shear)}$$

where

$$\frac{b/t}{\sqrt{K}} \leq \sqrt{\frac{\pi^2 E}{12\,(1 - \mu^2)0.7576\sigma_y}} \qquad (7)$$

The critical buckling stress shall be assumed to be

$$\sigma_{cr} = \frac{\sigma_y(\sigma_e K_\sigma)^2}{0.1836\,(\sigma_y)^2 + (\sigma_e K_\sigma)^2} \text{ (for compression)} \qquad (8)$$

$$\tau_{cr} = \frac{\sigma_y(\sigma_e K_\tau)^2}{\sqrt{3}\,[0.1836\,(\sigma_y)^2 + (\sigma_e K_\tau)^2]} \text{ (for shear)} \qquad (9)$$

These formulas assume $\sigma_y$ to be 1.32 times the proportional limit $\sigma_p$.

**4332 Combined Compression and Shear Buckling.** Taking $\sigma_c$ and $\tau$ to be the calculated compression and shear stresses, respectively, in a plate, the critical comparison stress shall be calculated as follows:

$$\sigma_{crc} = \frac{\sqrt{\sigma_c^2 + 3\tau^2}}{\left(\frac{1+\beta}{4}\right)\left(\frac{\sigma_c}{\sigma_{cr}}\right) + \left[\left(\frac{3-\beta}{4} \times \frac{\sigma_c}{\sigma_{cr}}\right)^2 + \left(\frac{\tau}{\tau_{cr}}\right)^2\right]^{1/2}} \qquad (10)$$

$\beta$ is the stress ratio as defined in Table 4332.1-1.

**4332.1 Design Factors in Plate Buckling (*DFB*).** (15) The critical comparison stress $\sigma_{crc}$ for plates shall be compared with the equivalent compression stress of

$$\sigma_{ce} = \sqrt{\sigma_c^2 + 3\tau^2}$$

Design factors *DFB* required for buckling are as follows ($\beta$ is defined in Table 4332.1-1):

| Crane Loading Condition | Design Factor *DFB* |
|---|---|
| Operating | $2 + 0.3\,(\beta - 1) \geq 1.40$ |
| Construction | $2 + 0.3\,(\beta - 1) \geq 1.40$ |
| Severe environmental | $1.5 + 0.125\,(\beta - 1) \geq 1.25$ |
| Extreme environmental | $1.35 + 0.075\,(\beta - 1) \geq 1.20$ |

Therefore,

$$\sigma_{ce} \times DFB \leq \sigma_{crc}$$

**4333 Proportion for Fabricated Box Girders.** The ratio of $l/h$ shall not exceed 25; the ratio of $l/b$ shall not exceed 60; and the ratio of $b/t$ shall not exceed

$$\sqrt{\frac{(2.62 \times 10^7)K_\sigma}{\sigma_p} \times \frac{2}{DFB}} \text{ (operating condition)}$$

(where $b$ is the unsupported plate width between longitudinal stiffeners, webs, or cover plate) or $30.99\sqrt{K_\sigma(2/DFB)}$ operating condition for A36 steel.

- $b$ = distance between web plates, in.
- $h$ = depth of web, in.
- $l$ = span, in.
- $t$ = thickness of web plate

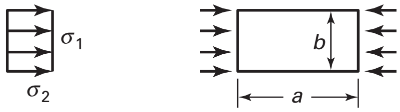
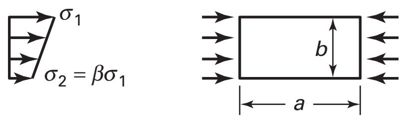
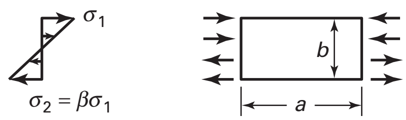
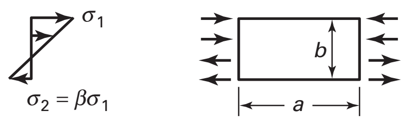
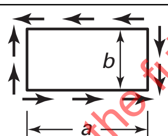
**4334 Spacing of Transverse Stiffeners.** The spacing of the transverse stiffeners $a$, in., shall not exceed the amount given by the formula

$$a = \frac{11{,}068t}{\sqrt{\tau c}}$$

where

- $c$ = spacing coefficient (see table below)
- $t$ = thickness of the web plate, in.
- $\tau$ = shear stress in plate, psi

**Table 4332.1-1 Value of the Buckling Coefficients, $K_\sigma$ and $K_\tau$, for Plates Supported at Their Four Edges**

| No. | Case | | $\alpha = \frac{a}{b}$ | $K_\sigma$ or $K_\tau$ |
|---|---|---|---|---|
| 1 | Simple uniform compression: $\sigma_1 = \sigma_2$ |  | $\alpha \geq 1$<br>$\alpha < 1$ | $K_\sigma = 4$<br>$K_\sigma = \left(\alpha + \frac{1}{\alpha}\right)^2$ |
| 2 | Nonuniform compression: $0 < \beta \leq 1$ |  | $\alpha \geq 1$<br>$\alpha < 1$ | $K_\sigma = \frac{8.4}{\beta + 1.1}$<br>$K_\sigma = \left(\alpha + \frac{1}{\alpha}\right)^2 \cdot \frac{2.1}{\beta + 1.1}$ |
| 3 | Pure bending: $\beta = -1$ or bending with tension preponderant: $\beta < -1$ |  | $\alpha \geq 2/3$<br>$\alpha < 2/3$ | $K_\sigma = 23.9$<br>$K_\sigma = 15.87 + \frac{1.87}{\alpha^2} + 8.6\alpha^2$ |
| 4 | Bending with compression preponderant: $-1 < \beta < 0$ |  | | $K_\sigma = (1 + \beta)K' - \beta K'' + 10\beta(1 + \beta)$<br>where<br>$K'$ = value of $K_\sigma$ for $\beta = 0$ in Case No. 2<br>$K''$ = value of $K_\sigma$ for pure bending (Case No. 3) |
| 5 | Pure shear |  | $\alpha \geq 1$<br>$\alpha < 1$ | $K_\tau = \left(5.34 + \frac{4}{\alpha^2}\right)\sqrt{3}$<br>$K_\tau = \left(4 + \frac{5.34}{\alpha^2}\right)\sqrt{3}$ |

GENERAL NOTE: The definitions of $K_\sigma$ and $K_\tau$ are in this Table, and depend on the ratio $\alpha = a/b$ of the two sides of the plates, the manner in which the plate is supported along its edges (simply supported), and the type of loading sustained by the plate. For other cases than those covered by this Table, further appropriate analysis should be made.



nor shall it exceed 72 in. or $h$, the depth of the web, whichever is greater.

| Loading Condition | Spacing Coefficient |
|---|---|
| Operating | 1.00 |
| Construction | 1.00 |
| Severe environmental | 0.75 |
| Extreme environmental | 0.60 |

**4335 Stiffness of Longitudinal and Transverse Stiffeners.** The required stiffness of the longitudinal stiffener and the stiffness of the transverse stiffeners shall be in accordance with CMAA 70.

### 4340 Allowable Deflections and Cambers

(15) **4341 Girder Deflection.** The maximum vertical deflection of the girder resulting from the weight of the trolley and rated load ($P_{dr} + P_{lr}$) shall not exceed $\frac{1}{1,000}$ of the span for Type I cranes or $\frac{1}{888}$ of the span for Types II and III cranes. Also, the maximum vertical deflection of the girder resulting from the weight of the trolley and construction load ($P_{dt} + P_{cn}$) shall not exceed $\frac{1}{600}$ of the span. The weight of the bridge and the vertical inertia forces shall not be included in determining deflections.

The total vertical or lateral deflection of the girder during environmental loading shall be limited such that displacements do not cause the girder or any of its attachments to become dislodged or to leave the crane.

**4342 Girder Camber.** Box girders shall be cambered an amount equal to the dead load deflection plus one-half of the deflection caused by the rated load and trolley [camber $= \Delta P_{db} + 0.5\Delta(P_{dt} + P_{lr})$]. (15)

**4343 Trolley Frame Deflection.** The trolley frame shall be of rigid construction such that lifted loads do not cause deflections that impair the proper operation of machinery.

**4344 Miscellaneous Structure Deflection.** Deflections of components such as end ties, end trucks, saddles, and equalizer beams shall not impair the functions for which they were designed or cause any attachments to the crane to become dislodged or to leave the crane.

**4345 Gantry and Semigantry Crane Structural Deflection.** The following additional requirements shall apply to gantry and semigantry cranes: (15)

(a) The girder deflection of gantry and semigantry cranes shall not exceed that stated in para. 4341 when the deflection is calculated as a simply supported beam, where the girder span of a gantry crane is the center-to-center distance of the legs at their connections to the girder and the girder span of a semigantry crane is the distance from the upper crane rail to the center of the leg at its connection to the girder.

*(b)* The total vertical deflection of the girder cantilever shall not exceed $^1/_{500}$ of the cantilever length for the rated live load plus trolley ($P_{dt} + P_{lr}$) when the deflection is calculated as a fixed end cantilever beam.

*(c)* Side thrust at the runway rail due to gantry leg spreading caused by girder span or cantilever deflection or thermal movement shall be held at an acceptable level by providing adequate clearance between the rail head and the wheel flanges, or by means of other design features incorporated into the gantry structure.

### 4350 Fatigue Requirements

Cranes used for nuclear power plants are normally used relatively few times during the entire life of the plant, as compared to typical structural fatigue criteria. The number of times a typical crane is cycled from no live load to full capacity load seldom exceeds 20,000 cycles during the entire life of the crane. Because of the combined effect of low full-load cycles and low allowable stresses during normal operation, the allowable stresses for the structural members, as specified in para. 4310, need not be reduced due to fatigue.

If the purchaser determines that greater than 20,000 full-load cycles are required, the purchaser shall then specify the cycles and load class per CMAA 70. The allowable stresses for the appropriate service level in CMAA 70 shall be used, but shall not exceed the basic operating stress allowables specified in para. 4310.

## 4400 COMPONENT DESIGN

### 4410 General

**4411 Venting.** Closed sections used in structures that are subject to changes in pressure shall be vented. If used, vent openings shall be sized to equalize the internal closed section (or compartment) pressure with its external environmental pressure. Pressure rate of change tables or graphs may be required to determine maximum flow requirements. Where internal full depth diaphragms extend from the top flange to the bottom flange, the compartment formed by a pair of diaphragms shall be vented.

**4412 Drainage.** Box sections when required by environmental conditions shall be drained to prevent moisture from accumulating. Where internal full depth diaphragms extend from the top flange to the bottom flange, the compartment formed by a pair of diaphragms shall be drained. Holes shall be provided in the bottom flange of the box girder for draining the whole box girder or each compartment formed by the diaphragms.

**4413 Stress Concentrations.** Consideration shall be given to points where high stresses might be encountered, such as (but not limited to) at ends of stiffeners, intermittent welds, points of attachment, cutouts, and reentrant corners. All reentrant corners shall be shaped notch free to a radius of at least ½ in. Sharp corner cuts are to be avoided, as are abrupt changes in section properties. Cutouts, where necessary, shall be made with rounded corners, and their edges shall be analyzed for reinforcement.

### 4420 Bridge Girders

**4421 General.** The crane girders (bridge girders) shall be fabricated of structural steel. Structural steel materials shall comply with the requirements of para. 4210. Construction of the crane girders can be of several types, namely, welded plates to form box sections, box sections fabricated from rolled shapes with or without plates, single-rolled shapes, or built-up single web plate girders.

**4422 Loading Criteria.** Bridge girders shall be designed to resist the load combinations specified in para. 4140. When bridge girders and end ties are moment-connected in the horizontal plane, the assembly shall be analyzed as a rigid frame for the transverse horizontal loads.

#### 4423 Fabricated Box Girders

**4423.1 Proportions.** Proportions for fabricated box girders shall be as specified in para. 4333.

**4423.2 Stiffeners.** The requirements of longitudinal and vertical stiffeners are given in para. 4330. Internal full depth diaphragms are required at machinery attachment points, bridge drive supports, and line shaft bearing supports.

The diaphragms may also be considered to meet the requirements of the vertical stiffeners. External stiffeners adjacent to the diaphragms may be required to transmit forces from the attachments into the girder.

**4423.3 Diaphragms.** All internal diaphragms shall be fitted to bear against the top cover plate to support the trolley rail, and shall be welded to the web plates to transfer the rail load directly to the box girder webs.

**4423.4 Diaphragm Spacing.** Short diaphragms shall be placed between full depth diaphragms so that the maximum distance between adjacent diaphragms will limit the maximum bending stress without impact in the trolley rail to $\sigma_{ab}$

$$\sigma_{ab} = \frac{\text{(trolley wheel load, lb)(distance between diaphragms, in.)}}{6\text{ (minimum section modulus of rail, in.}^3\text{)}}$$

For operating and construction loading, $\sigma_{ab}$ = 18,000 psi. For severe environmental loads, $\sigma_{ab}$ = 24,000 psi. For extreme environmental loads, $\sigma_{ab}$ = 32,400 psi.

The top cover plate of the box girder shall not be considered as contributing to the bending properties of the trolley rail.

**4423.5 Diaphragm Thickness.** The thickness of the diaphragm plate shall be sufficient to resist the trolley wheel load in bearing, on the assumption that the wheel load is distributed over a distance equal to the width of the rail base plus twice the distance from the rail base to the top of the diaphragm plate.

**4424 Single Web Girders.** Single web girders may be standard rolled beams or plate girders, reinforced with angles, channels, or plates. Where necessary, auxiliary girders shall be used to support overhanging loads to minimize torsional moments and lateral deflections on the single web girder. The analysis required for single web girders shall be the same as required for the plate box girder in para. 4423. The design shall be in accordance with the AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings, but with the allowable stresses set forth in para. 4310.

### 4430 Trolley Frames

**4431 Construction.** The trolley frame shall be constructed of structural steel. If field assembly of the trolley structure is required, the connections shall be designed to ensure proper alignment of the components.

#### 4432 Design

**4432.1 Trolley Frame.** The trolley frame shall be designed to resist all loading imposed by the motor, gearing, lifted load, and the load combinations specified in para. 4140.

**4432.2 Load Girt.** The load girt(s) shall be designed to carry the load to the side frames. Care shall be taken that the load girt deflections do not adversely affect the machinery alignment.

**4433 Axle Failure.** Provisions shall be made to prevent a drop of more than 1 in. in case of an axle failure.

### 4440 End Trucks and End Ties

#### 4441 End Trucks

**4441.1 General.** The end truck is the assembly consisting of wheels, bearings, axles, and structural frame that supports the crane bridge.

**4441.2 Construction.** The end trucks shall be constructed of structural steel.

**4441.3 Design.** The end truck shall be designed to support the maximum crane end reactions for the load combinations specified in para. 4140.

**4441.4 Axle Failure.** Provisions shall be made to prevent a drop of more than 1 in. in case of an axle failure.

**4441.5 Wheel Base.** The wheel base of the end trucks of four-wheel cranes, or center-to-center of outermost wheels of multiple end trucks for cranes with more than four wheels, shall be not less than one-seventh of the girder span.

**4441.6 Rail Sweeps.** A rail sweep shall be provided in front of each outside wheel. The rail sweep shall project below the top of the bridge runway rail.

#### 4442 End Ties

**4442.1 Construction.** The end tie shall be constructed of structural steel.

**4442.2 Types.** End ties for cranes with more than four bridge wheels can be either the flexible or rigid type. If equalizer bridge trucks are incorporated into the end carriage design to promote equal sharing of bridge wheel loads, and equalizer pins are provided between the equalizer trucks and equalizer beam and/or the rigid bridge frame structure, a rigid-type end tie may be used. If equalizer pins are not provided between the equalizer trucks and equalizer beam and/or the rigid bridge frame structure, a flexible end tie must be used.

**4442.3 Design.** End ties shall be designed to resist the loads due to crane movement and the load combinations specified in para. 4140.

A rigid frame analysis shall be used to determine the proportions of the loads resisted by the end ties and by the girders. The flexible end tie shall be designed to accommodate up to $\frac{1}{4}$ in. difference in elevation of the bridge rail between any wheels or pair of wheels without exceeding allowable stresses.

### 4450 Gantry Frames

**4451 General.** Gantry frames shall be fabricated of structural steel. The structural members assembled to form the gantry frame may include, but are not limited to, the following: girders, end ties, legs, trucks, sills, struts, saddles, and equalizer beams. Structural steel materials used in the gantry frame members shall comply with the requirements of para. 4210.

**4452 Loading Criteria.** Gantry frames shall be designed to resist the load combinations specified in para. 4140. The gantry frame assembly shall be analyzed as a three-dimensional structure.

**4453 Gantry Legs.** Gantry legs shall be designed to withstand the load combinations specified in para. 4140. The legs shall be constructed of structural steel, and their configuration may vary according to the clearance and overall crane geometry required.

Gantry legs constructed of box sections shall be provided with diaphragms to maintain the leg geometry. The legs shall be stiffened to meet the requirements of para. 4330.

**4454 Struts and Sills.** Struts and sills are used to connect the legs and joining members. They shall be designed to resist the load combinations specified in para. 4140. Struts and sills shall be constructed of structural steel.

**4455 Saddles and Equalizer Beams.** Saddles and equalizer beams are used to support the crane structure and are themselves supported by the gantry trucks. Their purpose is to distribute the loading at one corner of the crane equally to the bridge wheels at that corner. They shall be constructed of structural steel. Saddles and equalizer beams shall be designed for the load combinations specified in para. 4140.

Plates or hubs used in saddles or equalizer beams to support trunnions and rotating pins shall be designed to meet the bearing stress specified in Section 5000.

**4456 Gantry Wheel Base.** The wheel base of the end trucks of four-wheel gantry cranes, or center-to-center of extreme wheels of multiple end trucks for gantry cranes with more than four wheels, may be required to exceed that ratio specified in para. 4441.5. The gantry structure height may necessitate an increased wheelbase in order to gain gantry stability and to reduce gantry skewing.

**4457 Gantry Stability.** The gantry crane shall have a safety factor of not less than 1.5 against overturning when used in the unrestrained operating condition and subjected to the load combinations specified in para. 4140. During severe environmental, extreme environmental, or abnormal event loading, the gantry crane shall have a safety factor of not less than 1.1 against overturning. Restraints may be used to prevent overturning.

## 4460 Rails

**4461 Requirements.** All bridge and trolley rails required to transmit vertical down and horizontal loads due to normal and construction loads only shall conform to the ASCE, ARA, or AREA specifications. When these rails are used on Types I and II cranes, secondary restraints that are not necessarily in contact under normal loading conditions shall be provided to resist the vertical up and horizontal loads due to severe environmental and extreme environmental loading conditions. Rails required to transmit vertical up and/or horizontal loads due to severe environmental and extreme environmental loading conditions shall meet all of the requirements of a structural steel member as covered in paras. 4200 and 4300.

**4462 Fastening.** Bridge and trolley rails shall be joined by standard joint bars or welded. For other than polar crane runway rails, provision shall be made to prevent creeping of the rails by means of a positive stop at the ends of the rail. Rails shall be securely fastened in place to maintain center-to-center distance of rails. Fastening of rails to the supporting structure shall be appropriate to transfer the calculated horizontal and vertical forces.

## 4470 Footwalks, Handrails, Platforms, Stairs, and Ladders

**4471 General.** Platforms and footwalks shall be provided as required for access and maintenance. Dimensions and clearances for footwalks, handrails, platforms, stairs, and ladders shall be in accordance with the latest edition of OSHA.

**4472 Materials.** Materials for construction of footwalks, handrails, platforms, stairs, and ladders shall meet the requirements of para. 4200, except that the requirements of para. 4212 need not be considered. ASTM A569 is an acceptable material for metal bar grating.

**4473 Design.** Footwalks, handrails, platforms, stairs, and ladders shall be designed for the appropriate dead load and the live loads as specified in the OSHA standards. Structural design shall be in accordance with para. 4300.

## 4480 Operator's Cab

**4481 General**

*(a)* The standard location of the operator's cab shall be at one end of the crane bridge on the driving girder side unless otherwise specified. It shall be so located as not to interfere with the hook approach. The operator's cab shall be open type for indoor service unless otherwise specified. Dimensions and clearances shall be in accordance with the latest edition of OSHA.

*(b)* Cabs shall be provided with ladder or stairway leading to the bridge footwalk.

*(c)* The arrangement of equipment in the cab shall be approved by the purchaser.

*(d)* Cabs shall be designed for maximum operator visibility. A visibility diagram shall be furnished to the purchaser for approval.

*(e)* If specified by the purchaser, the cab shall be provided with heating, ventilating, and/or air-conditioning.

*(f)* The operator's cab shall have a clear height, with equipment installed, of not less than 7 ft. Provision shall be made in the operator's cab for placement of the necessary equipment, wiring, and fittings. All cabs should be provided with a swiveled seat unless otherwise specified.

**4482 Materials.** Materials for construction of the operator's cab shall meet the requirements of para. 4200, except that the requirements of para. 4212 need not be considered.

**4483 Design.** The operator's cab shall be designed for appropriate dead and live loads. Structural design shall be in accordance with para. 4300.

### 4484 Construction

**4484.1 Enclosed Cabs.** Enclosed cabs shall have watertight plate roofs that slope to the rear and shall be provided with sliding, hinged, or drop windows on the three sides, and with sliding or hinged doors. Steel plates for enclosing sides, when used, shall be not less than $\frac{1}{8}$-in. thick. The window sash shall be equipped with clear shatterproof glass installed from the inside so that if it is dislodged it will fall in the cab. Drop windows shall be protected from breakage by a $\frac{1}{8}$-in. sheet steel guard, extending to within 2 in. of the floor, and shall be provided with handles and stops that will prevent catching the user's hands or toes when operating the windows. Drop windows shall be counterweighted.

**4484.2 Open Cabs.** Open cabs shall be enclosed with panels not less than $\frac{1}{8}$-in. thick or standard railing 42-in. high. Railing enclosures shall be provided with midrail and steel toe plate. Where the top rail, or top of the panel, interferes with the operator's vision, it may be lowered, with the purchaser's approval.

# Section 5000
# Mechanical

## (15) 5100 GENERAL

Section 5000 specifies design criteria for mechanical components of Types I, II, and III cranes. Unless otherwise stated, the design requirements and allowable stresses are based on Allowable Stress Design (ASD) using classical Mechanics of Materials/Strength of Materials methodologies.

### 5110 Load Spectrum Crane Classification

#### 5111 Type I Cranes

*(a)* The design of the mechanical components of the crane is based on the loading conditions, the operating frequency, and the operating cycle in respect to the function within the facility. This specific load spectrum information, or a realistic estimate of the anticipated load spectrum, shall be conveyed to the crane manufacturer by the purchaser.

*(b)* For a crane having a specific operating cycle such as a typical polar crane, the service condition (load spectrum) can be determined by the number of operating cycles per hour, the type and magnitude of applied loads, the distance of travel motion, and the number of operating hours by given time period. The user shall also establish the service life and reliability requirements for the crane, considering such factors as technical, economic, environmental, and probability of obsolescence. This information is important so that the designer can then provide for the fatigue strength for the components of the crane to meet the requirements of the intended service. The information will provide the basis for the fatigue strength and fatigue life data criteria of the component design, which will require that a numerical documentation of the crane service requirements be in a form that will represent the duty cycle for the crane. This duty cycle or service data for each individual motion of the crane shall be recorded on the Crane Service Data Record Form 1.00 (see Fig. I-5111), and shall become part of the contract between the crane manufacturer and the purchaser.

*(c)* The design for fatigue analysis shall be considered for the critical components of the crane mechanical components. The cumulative fatigue usage factors shall reflect the effects of all loads sustained from both the construction and operating periods. In absence of a complete certified crane load cycle or load spectrum, the following criteria shall govern:

*(1)* All mechanical components in the critical load path, or whose failure could result in uncontrolled movement of a critical load, shall be designed for infinite fatigue life.

*(2)* Travel drives are exempted from infinite fatigue analysis where the maximum excursions due to any postulated failure are facility acceptable.

*(3)* Fatigue analysis shall be based on crane maximum rated load.

*(4)* Design consideration shall be taken to ensure that the failure of catalog-purchased components during the projected life of the crane will not result in facility unacceptable excursion of the critical load.

**5112 Types II and III Cranes.** The load spectrum of Types II and III cranes shall be in accordance with specification CMAA 70 classifications.

### 5120 Hoisting Units

#### 5121 Type I Cranes

*(a)* The hoist components shall meet the requirements of this Standard, as applicable.

*(b)* The hoist drive system shall be designed to provide assurance that a failure of a single hoist mechanism component would not result in the uncontrolled movement of the lifted load. This can be accomplished by the application of a single (Fig. 5416.1-1), dual (Fig. 5416.1-2), and/or redundant (Fig. 5416.1-3) hoist machinery arrangement. The wire rope drum is exempted from this requirement.

*(c)* Critical load excursions due to failure in the dual load path shall be determined and certified as to facility acceptability.

*(d)* Hoisting machinery shall be designed for the maximum braking torque.

*(e)* The hoisting machinery and wire rope reeving system, in addition to other affected components, shall be designed to withstand the most severe potential overload, including two-blocking and load hangup, with allowable stresses limited in accordance with paras. 5321.2 and 5425.1. Design calculations and component sizing shall take into consideration the maximum forces resulting from the kinetic energy of the hoisting machinery operating at maximum normal full-load or unloaded operating speed at the onset of the overload condition. Motor stall torque shall be considered, as well as all

other factors contributing to maximum loading of the equipment components. The system or components (which may include torque-limiting or energy-absorbing components or systems) used to mitigate the effects of two-blocking and load hangup shall permit the hoisting machinery and crane to be returned to service without need for repair or replacement of components. Should any device in the hoist drive train (including but not limited to a clutch or torque limiting means) fail to hold the load, the emergency brake (or other secondary/redundant load path) shall be caused to engage (or remain engaged) and safely retain the load.

**5122 Types II and III Cranes.** Hoist components of Types II and III cranes shall be in accordance with CMAA 70, except as specified herein. Hoisting machinery shall be designed for the maximum braking torque.

## 5130 Bridge and Trolley Drives

### 5131 Type I Cranes

*(a)* Drive components shall meet the requirements of this Standard, as applicable.

*(b)* In travel drives, single-failure-proof features are generally not required. However, in those cases where a failure in the braking mode could result in a facility unacceptable excursion, the design shall incorporate single-failure-proof features to ensure that the crane can be brought to a safe stop.

*(c)* A manual means shall be provided to move the trolley and bridge when power is not available.

**5132 Types II and III Cranes.** Drive components shall be in accordance with CMAA 70, except as specified herein.

## 5140 General Mechanical Components

**5141 Type I Cranes.** Couplings, wheels, axles, drive shafts, bearings, fasteners, gear cases, enclosures, guards, bumpers, stops, and limit switches shall meet the requirements of this Standard, as applicable.

**5142 Types II and III Cranes.** General mechanical components shall be in accordance with CMAA 70, except as specified herein.

## 5150 Critical Items

Critical items for a single-failure-proof handling system on a Type I crane are those components that are located between the load and the source of energy holding the load.

*(a)* These components require special consideration as to material, design, control of manufacturing processes, and examination of final product.

*(b)* Table 7210-1 lists the tests and the inspections that are to be applied to critical items in accordance with the requirements of Section 7000.

*(c)* The acceptance criteria for all items listed in Tables 7210-1 and 7210-2 shall be in accordance with para. 7100.

## 5160 Nomenclature

The following nomenclature is used in Section 5000 and is listed according to the article heading where it appears.

### 5161 Drum Shell Design (See Para. 5411.5) (15)

$DFB$ = design factor for buckling/yield
$d_r$ = drum root diameter at rope grooves, in.
$E$ = modulus of elasticity, psi
$M_B$ = maximum bending moment of drum shell, in.-lb
$P$ = pitch of drum rope, in.
$R_L$ = maximum hoist rope load on drum, lb
$t_n$ = nominal drum shell thickness, in.
$t_s$ = minimum drum shell thickness, in.
$Z_B$ = section modulus of drum shell, in.$^3$
$\Delta t$ = reduction of nominal drum shell thickness, in.
$\mu$ = Poisson's ratio
$\tau_{all}$ = allowable shear stress, psi
$\tau_{max}$ = maximum shear stress, psi
$\sigma_{all}$ = allowable combined stress, psi
$\sigma_B$ = drum shell bending stress, psi
$\sigma_C$ = drum shell crushing stress, psi
$\sigma_{comb}$ = combined drum shell stress, psi
$\sigma_{cr}$ = critical buckling stress, psi
$\sigma'_{cr}$ = elastic critical buckling stress, psi
$\sigma_{ult}$ = minimum ultimate strength, psi
$\sigma_y$ = minimum yield stress, psi

### 5162 Allowable Strength Horsepower, $P_{at}$ (Gearing) [See Para. 5413.1(a)]

$d$ = operating pitch diameter of pinion, in.
$F$ = net face width of narrowest member of the mating gears, in.
$J$ = geometry factor for bending strength
$K_B$ = rim thickness factor
$K_m$ = load distribution factor
$K_v$ = dynamic factor
$n_p$ = pinion speed, rpm
$P_{at}$ = allowable transmitted power for bending strength, hp
$P_d$ = transverse diametral pitch, in.$^{-1}$
$S_{fs}$ = crane class factor (strength)
$s_{at}$ = allowable bending stress number, psi

### 5163 Allowable Durability Horsepower, $P_{ac}$ (Gearing) [See Para. 5413.1(b)]

$C_H$ = hardness ratio factor for pitting resistance
$C_p$ = elastic coefficient, (psi)$^{1/2}$
$d$ = operating pitch diameter of pinion, in.
$F$ = net face width of narrowest member of the mating gears, in.
$I$ = geometry factor for pitting resistance

$K_m$ = load distribution factor
$K_v$ = dynamic factor
$n_p$ = pinion speed, rpm
$P_{ac}$ = allowable transmitted power for pitting resistance, hp
$S_{fd}$ = crane class factor (durability)
$s_{ac}$ = allowable contact stress number for material, psi

**5164 Allowable Momentary Overload, $W_{tov}$ (Gearing) [See Para. 5413.1(c)]**

$F$ = net face width of the narrowest member of the mating gears, in.
$J$ = geometry factor for bending strength
$P_d$ = transverse diametral pitch, in.$^{-1}$
$s_{ay}$ = allowable yield stress number for material, psi
$W_{tov}$ = allowable momentary overload, lb

**5165 Gear Efficiencies [See Para. 5413.1(g)]**

$E$ = efficiency
$N$ = number of gear reductions

**5166 Reeving Efficiency (See Para. 5429)**

$E$ = overall combined efficiency
$E_d$ = combined efficiency of ropes on drum and antifriction bearings
$E_g^n$ = combined efficiency of gear reductions and antifriction bearings
$E_s^m$ = combined efficiency of rope on sheaves
$m$ = total number of rotating sheaves divided by the number of ropes off drum
$n$ = number of gear reductions

**5167 Table 5452.3-1**

$b$ = effective width rail head, in.
$D$ = diameter of wheel, in.
$P$ = allowable wheel load, lb

**5168 Nomenclature (Analytical Procedures; See Para. 5472)**

*(a) Symbols*

$A$ = effective cross-sectional area of critical section, in.$^2$
$D$ = large diameter of a stepped shaft or round bar, in.
$d$ = small diameter of a stepped shaft or round bar, in.
$I$ = moment of inertia, in.$^4$
kip = 1,000 lb
ksi = kips per sq in.

*(b) Equivalent Stress Factors*

$K_{EB}$ = for combining bending and shear stresses
$K_{EN}$ = for combining tension–compression and shear stresses
$K_{EXY}$ = for combining biaxial stresses

*(c) Stress Concentration Factors*

$K_{NB}$ = for bending
$K_{NN}$ = for tension–compression
$K_{NS}$ = for shear
$K_{NT}$ = for torsion

*(d) Service Factors*

$K_{SB}$ = for bending
$K_{SN}$ = for tension–compression
$K_{SS}$ = for shear
$K_{ST}$ = for torsion

*(e) Moments and Forces*

$M_B$ = bending moment, in.-kip
$M_T$ = torsional moment, in.-kip
$P$ = load (weight, force, or transverse shear load reaction), kips
$Q$ = static moment about the neutral axis of the area of that portion of the component cross-section beyond the place where the shear is being calculated, in.$^3$
$r$ = fillet radius, in.

*(f) Stress Fluctuation Ratios*

$R_B$ = $\sigma_B$ min./$\sigma_B$ max. for bending
$R_N$ = $\sigma_N$ min./$\sigma_N$ max. for tension–compression
$R_S$ = $\tau_S$ min./$\tau_S$ max. for shear
$R_T$ = $\tau_T$ min./$\tau_T$ max. for torsion

*(g) Dimensions and Properties*

$S_B$ = section modulus, in.$^3$
$S_T$ = polar section modulus, in.$^3$
$t$ = thickness of component where stress is being calculated, in.
$\sigma_{UT}$ = minimum ultimate tensile strength at mid-radius, ksi

*(h) Maximum Allowable Stresses*

$\sigma_{BA}$ = for bending, ksi
$\sigma_{NA}$ = for tension–compression, ksi
$\sigma_{XA}$ = for stress about the X axis, ksi
$\sigma_{YA}$ = for stress about the Y axis, ksi
$\tau_A$ = for combined (equivalent) shear, ksi
$\tau_{TA}$ = for torsional shear (equivalent torsional shear) stress

*(i) Working Stresses*

$\sigma_B$ = bending stress, ksi
$\sigma_{EB}$ = equivalent bending (bending and shear) stress, ksi
$\sigma_{EBN}$ = equivalent bending (bending and tension-compression) stress, ksi
$\sigma_{EN}$ = equivalent tension–compression (tension–compression and shear) stress, ksi
$\sigma_{EXY}$ = equivalent biaxial stress, ksi
$\sigma_{EXYT}$ = equivalent stress (biaxial and shear), ksi
$\sigma_N$ = tension–compression stress, ksi
$\sigma_X$ = normal stress about the X axis, ksi
$\sigma$ = normal stress about the Y axis, ksi
$\tau_{ET}$ = equivalent torsional shear stress, ksi

$\tau_S$ = shear stress, ksi
$\tau_T$ = torsional shear stress, ksi
$\tau_{XY}$ = shear stress in the X–Y plane including torsion, ksi

### 5169 Analytical Method for Hook of Approximate Trapezoidal Shape (See Para. 5477)

$A$ = area of cross-section, in.$^2$
$b_i$ = inside width of equivalent trapezoid
$b_o$ = outside width of equivalent trapezoid
$h_o$ = depth of equivalent trapezoid
$K_f$ = factor
$r_i$ = inside radii of equivalent trapezoid
$r_o$ = outside radii of equivalent trapezoid
$S_b$ = stress bending
$S_i$ = stress-direct tension
$S_{max}$ = stress maximum
$S_o$ = stress augment

## 5200 MATERIALS

### (15) 5210 Material (Type I Crane)

Nonmetallic materials shall not be used for components within the load path of the lifted load, with the exception of brake friction material. Cast iron with less than 15% elongation shall not be used for components within the load path of the lifted load, with the exception of electric motor frames, hydraulic components, and brake wheels. Also, with the exception of sleeve and thrust bearings, friction components, or as otherwise noted below, hoist components shall be made of steel, and the material elongation properties of the following components shall not be less than 12%:

*(a)* hook and hook nut
*(b)* hook trunnion or cross-head
*(c)* load block frame/structure
*(d)* upper block frame/structure
*(e)* equalizer frame/structure
*(f)* sheaves
*(g)* sheave pins
*(h)* equalizing bar pins
*(i)* shafting and external shafting bearing housings
*(j)* shafting keys and couplings (including hoist drum couplings)
*(k)* hoist drum components and external drum shaft bearing housings
*(l)* hoist drum retention components [components required per para. 5411.7(b) requirements]
*(m)* gear case housings (Gear case housings may be cast from ductile iron with not less than 15% elongation, provided they are not subjected to welding or brazing.)
*(n)* gearing using Grade 1 material per AGMA 2001-C95 (Grade 2 or 3 materials per AGMA 2001-C95 with less than 12% elongation are acceptable.)

### 5220 Material (Types II and III Cranes)

Materials shall be in accordance with CMAA 70.

## 5300 DESIGN AND PERFORMANCE CRITERIA

### 5310 Load Combinations

*(a)* The individual mechanical components of the overhead or gantry crane shall be designed to provide a design factor specified for that component to resist the forces resulting from the combination of loading specified for the component. The load combinations that must be considered for the individual components vary with the component, and frequently include maximum loadings calculated in the electrical or structural section, i.e., motor torque of a motor or live load including wind and impact.

*(b)* Certain components must be designed for seismic loading as a part of the load combinations. If a lump mass approach is used in the seismic design, the methods of structural design calculations within Section 4000 will provide the values of the dynamic analysis that will be determined for location, magnitude, and direction for forces to be used as equivalent static loading. The extent of seismic consideration necessary for the three types of cranes is as follows.

*(1) For Type I Cranes.* Seismic loading shall be only to ensure retention of the load and the prevention of any component from becoming a missile that would be detrimental to the facility's safety related equipment.

*(2) For Type II Cranes.* Seismic considerations shall be made to ensure that no component of the crane could become a missile that would be detrimental to the facility's safety related equipment.

*(3) For Type III Cranes.* Seismic analysis is not required unless specified by the purchaser.

**5311 Design Loads — Hydraulic Components for Types I, II, and III Cranes.** The design selection for hydraulic components shall be based on the rated load.

### 5320 Allowable Stresses

#### 5321 Type I Cranes

**5321.1 Normal Operating Conditions.** All load combinations and factors, including stress concentrations, shall have a service factor of 1.0 or more based on the design fatigue allowable stress limit of the material, except as otherwise specified in Section 5000.

$$\text{service factor} \times \text{design stress} \leq \text{allowable stress}$$

**5321.2 Load Hangup Conditions.** For load hangup conditions, the stresses based on the gross cross-section, excluding stress concentration factors, shall have a service factor of 1.0 or more, based on the allowable stress of 75% of the material's yield strength, except where otherwise specified in Section 5000. High bearing stresses within a component shall be limited to the material's yield strength when, by their nature, these stresses will not result in a loss of load.

**5321.3 Seismic Conditions.** For seismic conditions, the stresses based on gross cross-section, excluding stress concentration factors, shall not exceed the allowable stresses stated in para. 5481 except where otherwise specified in Section 5000. High contact and bearing stresses within a component are exempt from this requirement when, by their nature, these stresses will not result in a loss of load.

### 5322 Type II Cranes

**5322.1 Normal Operating Conditions.** All load combinations and factors, including stress concentrations, shall have service factors as stated for the design of specific mechanical components.

**5322.2 Load Hangup Conditions.** This is not applicable for a Type II crane, unless specified by the purchaser or owner.

**5322.3 Seismic Conditions.** For seismic conditions, the design shall be such that components that could damage safety-related equipment will remain in place during a seismic event.

### 5323 Type III Cranes

**5323.1 Normal Operating Conditions.** Allowable stresses shall be in accordance with the provisions of CMAA 70.

**5323.2 Load Hangup Conditions.** This is not applicable for a Type III crane, unless specified by the purchaser or owner.

**5323.3 Seismic Conditions.** This is not applicable for a Type III crane, unless specified by the purchaser or owner.

### 5324 Hydraulic Components — Allowable Stresses

**5324.1 Types I, II, and III Cranes.** Stresses imposed by the maximum rated load shall not exceed 20% of the average ultimate strength of the material or components.

## 5330 Motion Speeds

Rated load speeds for hoist, bridge, and trolley shall be such as to allow controlled handling of those loads for which the crane is designed. These speeds depend on the nature of the load, load clearances, position of operator, weight of load, positioning accuracy required, and type of drive. Design rated load speeds recommended in paras. 5331, 5332, and 5333 have been established based on typical operator reaction time and drive performance that will allow the load to be stopped and held.

### 5331 Hoist Speeds

**5331.1 Type I Hoists**

*(a)* The performance speed and speed tolerance of the hoist with rated load shall be specified by the purchaser. The rated load test (125% rated load or as specified by purchaser) speed criteria shall be as specified by the manufacturer.

*(b)* The slow speed column of Table 5331.1-1 shall be used for selecting hoist speeds. The design tolerance for rated load hoisting speed is ±10%.

*(c)* Hoisting speed for a critical load less than the rated load shall be limited to 125% of the rated load hoisting speed.

*(d)* Empty hook and light load speed-up controls are permitted. Refer to para. 6320(e).

*(e)* When precise positioning capability is required, and the principal control system is incapable of providing lowering speed control of 0.5 ft/min with the load as specified by the purchaser, the hoist system shall be equipped with an auxiliary system. The positioning capability speed should be 0.5 ft/min for a distance of 2 ft within the final position.

*(f)* The lowering speed for any critical load shall be limited to 125% of the rated load hoisting speed.

**Table 5331.1-1 Rated Load Recommended Hoist Speeds** (15)

| Rated Load, tons | Hoisting Speeds, ft/min Slow | Medium | Fast |
|---|---|---|---|
| 0–4 | 30 | 35 | 40 |
| 5–9 | 25 | 30 | 35 |
| 10–19 | 20 | 25 | 30 |
| 20–29 | 15 | 20 | 25 |
| 30–39 | 10 | 15 | 20 |
| 40–49 | 8 | 10 | 15 |
| 50–69 | 7 | 8 | 10 |
| 70–99 | 6 | 7 | 9 |
| 100–149 | 5 | 6 | 8 |
| 150–249 | 4 | 5 | 7 |
| 250–349 | 3 | 4 | 6 |
| 350–499 | 2 | 3 | 5 |
| 500–649 | 2 | 3 | 4 |
| 650–799 | 1 | 2 | 3 |
| 800–1,000 | 1 | 1.5 | 2 |

**5331.2 Types II and III Hoists.** Recommended rated load speeds should be as specified in either Table 5331.1-1 or the speed table given in CMAA 70.

### 5332 Trolley Speeds

**5332.1 Type I Cranes**

*(a)* The performance speed and speed tolerance of the trolley with rated load shall be specified by the purchaser. Rated load test speed (125% rated load) criteria shall be specified by the manufacturer.

*(b)* The slow speed column of Table 5332.1-1 shall be used for selecting trolley speeds. The design tolerance for a design rated load speed shall be ±10%.

(15) **Table 5332.1-1**
**Rated Load Recommended Trolley Speeds**

| | Trolley Speeds, ft/min | | |
|---|---|---|---|
| Rated Load, tons | Slow | Medium | Fast |
| 0–49 | 100 | 125 | 150 |
| 50–99 | 75 | 100 | 125 |
| 100–149 | 50 | 75 | 100 |
| 150–199 | 35 | 50 | 75 |
| 200–299 | 25 | 50 | 75 |
| 300–499 | 20 | 40 | 60 |
| 500–799 | 15 | 30 | 45 |
| 800–1,000 | 10 | 20 | 30 |

(15) **Table 5333.1-1**
**Rated Load Recommended Bridge Speeds**

| | Bridge Speeds, ft/min | | |
|---|---|---|---|
| Rated Load, tons | Slow | Medium | Fast |
| 0–49 | 125 | 150 | 175 |
| 50–99 | 100 | 125 | 150 |
| 100–149 | 75 | 100 | 125 |
| 150–199 | 50 | 75 | 100 |
| 200–299 | 40 | 75 | 100 |
| 300–499 | 30 | 50 | 75 |
| 500–799 | 25 | 35 | 50 |
| 800–1,000 | 15 | 20 | 30 |

*(c)* The trolley control shall provide an operating speed range of at least 10 to 1 under all loading conditions or be equipped with an auxiliary system to provide precise positioning capabilities.

*(d)* Trolley speed for a critical load less than rated load shall be limited to 125% of the rated load trolley speed.

*(e)* Empty hook and light load speed-up controls are permitted. Refer to para. 6340(c).

**5332.2 Types II and III Cranes.** Recommended rated load speeds should be as specified in either Table 5332.1-1 or the speed table given in CMAA 70.

### 5333 Bridge Speeds

**5333.1 Type I Cranes**

*(a)* The performance speed and speed tolerance of the bridge with rated load shall be specified by the purchaser. Rated load test speed (125% rated load) criteria shall be specified by the manufacturer.

*(b)* The slow speed column of Table 5333.1-1 shall be used for selecting bridge speeds. The design tolerance for a design rated load speed shall be ±10%.

*(c)* The bridge control shall provide an operating speed range of at least 10 to 1 under all loading conditions, or be equipped with an auxiliary system to provide precise positioning capabilities.

*(d)* Bridge speed for a critical load less than rated load shall be limited to 125% of the rated load bridge speed.

*(e)* Empty hook and light load speed-up controls are permitted. Refer to para. 6320(c).

*(f)* For cranes with circular polar-type bridges, the recommended speeds shall be the tangential speeds at the runway rail.

**5333.2 Types II and III Cranes.** Recommended rated bridge speeds should be as specified in either Table 5333.1-1 or the speed table given in CMAA 70.

### 5334 Pendant Hoist and Travel Speeds

**5334.1 Traversing.** Motorized travel speed for this motion should be 30 ft/min.

**5334.2 Vertical Travel of Control Pendant.** Motorized travel speed for this motion should be 30 ft/min.

### 5335 Powered Hook Rotation (Types I, II, and III Cranes)

*(a)* Speed of rotation shall be specified by purchaser.

*(b)* Rotation limit shall be specified by purchaser.

*(c)* Single-failure-proof features are not required.

## 5400 COMPONENT DESIGN

### 5410 Hoist System

### 5411 Drum

**5411.1 Description (Type I Cranes).** The drum shall be of cylindrical type, varying in length and diameter, and shall be so designed as to ensure the accumulation of the entire length of rope in one single layer.

**5411.2 Size (Type I Cranes).** The pitch diameter of the drum shall be not less than 24 times the hoist rope diameter for 6 × 37 rope construction, or not less than 30 times the hoist rope diameter for 6 × 19 rope construction.

**5411.3 Construction (Type I Cranes).** The hoist drum (in its entirety) shall be of steel construction. A rope guard flange shall be provided at both ends of the drum shell to prevent the hoist rope from spooling off either drum end. The drum shell and shafts shall be designed, per paras. 5411.5 and 5415, respectively. The drum end plates and internal plates, when used, shall be affixed to the shell. All welds shall be continuous (i.e., intermittent welds shall not be used). Welds shall be designed for infinite fatigue life ($10^7$ stress cycles) when handling the hoist's design rated load during normal operating conditions, with consideration for stress reversal and stresses resulting from localizing flexing of drum end plates, internal plates (if used), and the drum shell. The drum gear shall be press fitted and keyed to the periphery of the drum shell, end plate, hub, or drum shaft or be bolted in place with close fitting bolts (15) (para. 5456) to a drum drive flange, in which case the design shall be such that the bolts only transmit the drum torsional load.

**5411.4 Grooves (Type I Cranes).** Drum grooves shall be machined to a minimum depth equal to three-eighths of the diameter of the hoist rope, and a pitch equal to 1.14 × rope diameter or rope diameter + $\frac{1}{8}$ in., whichever is smaller. The groove radius shall be $\frac{1}{32}$ in. larger than the radius of the rope.

Rope shall be secured to the drum as follows: No less than two wraps of the rope shall remain on the drum at each anchorage to the hoisting drum when the hook is in its extreme low position. Rope end shall be anchored by a minimum of two clamps attached to the drum, or by a socket arrangement specified by the crane or rope manufacturer. The rope clamp bolts shall be tightened evenly to the manufacturer's recommended torque.

(15) **5411.5 Drum Shell Design (Type I Cranes).** The drum shell shall be of rolled or centrifugal cast steel, and shall be designed for both crushing and bending loads imposed by the hoist rope and drum brake loading, when used. The hoist rope loading on the drum shall include the effect of the rope reeving system efficiency. The drum shell thickness (effective material) shall account for machining tolerances, noneffective material on the inside of centrifugally cast tubes, inside diameter tolerances, inside diameter out-of-roundness tolerances, and inside diameter straightness tolerances due to camber and sweep.

*(a)* Drum shell stresses shall be calculated and combined in the following manner, and when a drum brake is used, the resulting stress shall be included:

*(1) Crushing Stress (Due to Rope Load)*

$$\sigma_C = R_L/(P \times t_S) \tag{1}$$

*(2) Bending Stress*

$$\sigma_B = M_B/Z_B \tag{2}$$

*(3) Maximum Shear Stress*

$$\tau_{max} = (|\sigma_C| + |\sigma_B|)/2 \tag{3}$$

*(4) Combined Stresses/Stress Intensity*

$$\sigma_{comb} = \left[(\sigma_C)^2 + (\sigma_B)^2 + |\sigma_C \times \sigma_B|\right]^{1/2} \tag{4}$$

NOTES:
(1) Additional rope loadings resulting from seismic forces, a load hang-up, or a hoist two-block event need not be included in calculating the drum crushing stress [eq. (1)].
(2) Since torsional and transverse shear stresses are relatively low in a hoist drum shell and have a negligible effect on its structural integrity, they need not be included when calculating the maximum shear stress and combined stresses [eqs. (3) and (4)].
(3) The absolute values of the crushing and bending stresses are required when calculating the maximum shear stress and combined stresses [eqs. (3) and (4)].

*(b)* Allowable stresses shall be determined in the following manner, which is based on both material properties and buckling stability. When the drum grooves are hardened, the core material properties shall be used (material properties at the mid-thickness).

*(1) Critical Buckling Stress.* The critical buckling stress is considered either elastic or inelastic, whereas it depends on the value of the elastic critical buckling stress relative to the minimum yield stress of the material.

The elastic critical buckling stress is determined in the following manner:

$$\sigma'_{cr} = \frac{E}{(1-\mu^2)} \times \left(\frac{t_S}{d_r}\right)^2 = 31.9 \times 10^6 \times \left(\frac{t_S}{d_r}\right)^2 \text{ psi} \tag{5}$$

If the elastic critical buckling stress is less than 50% of the minimum yield stress of the material, the critical buckling is considered elastic and is equal to the elastic critical buckling stress, whereas

$$\sigma_{cr} = \sigma'_{cr} \tag{6}$$

If the elastic critical buckling stress exceeds 50% of the minimum yield stress of the material, the critical buckling stress is considered inelastic and is determined in the following manner:

$$\sigma_{cr} = \sigma_y[1 - 0.25(\sigma_y/\sigma'_{cr})] \tag{7}$$

*(2) Allowable Stresses.* For normal operational loads and construction loads, the following are the allowable stresses, where *DFB* equals 2.0 for normal operational loads and *DFB* equals 1.67 for construction loads:

$$\tau_{all} = \sigma_{ult}/(5\sqrt{3})$$

$$\sigma_{all} = \sigma_{cr}/DFB$$

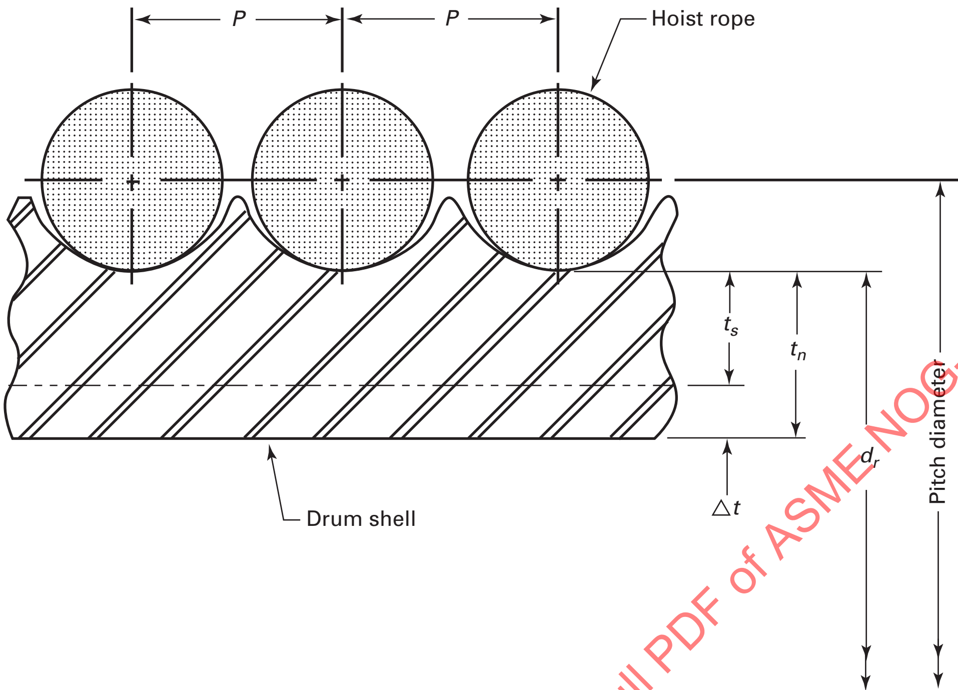
For extreme environmental and abnormal event conditions, the following is the allowable stress, where *DFB* equals 1.33:

$$\sigma_{all} = \sigma_{cr}/DFB$$

where

*DFB* = design factor for buckling/yield
$d_r$ = drum root diameter at rope grooves, in.
$E$ = modulus of elasticity of the material, psi (29,000,000 psi for steel)
$M_B$ = maximum bending moment of drum shell, in.-lb
$P$ = pitch of drum rope grooves as shown in Fig. 5411.5-1, in.

(15) **Fig. 5411.5-1 Drum Shell Design**






$R_L$ = maximum hoist rope load on drum without a dynamic load factor but including the effect of the rope reeving efficiency, lb
$t_n$ = nominal drum shell thickness at the bottom of rope grooves as shown in Fig. 5411.5-1, in.
$t_s$ = minimum drum shell thickness at rope grooves ($t_s = t_n - \Delta t$), in.
$Z_B$ = section modulus of drum shell based on root diameter ($d_r$) of drum grooves and the minimum drum shell thickness ($t_s$), in.[3]
$\Delta t$ = reduction of nominal drum shell thickness due to machining tolerances, noneffective material on the inside of centrifugally cast tubes, inside diameter tolerances, inside diameter out-of-roundness tolerances, and inside diameter straightness tolerances due to camber and sweep, in.
$\mu$ = Poisson's ratio (0.3 for steel)
$\tau_{all}$ = allowable shear stress based on average ultimate strength of the material, psi
$\tau_{max}$ = maximum shear stress in drum shell, psi
$\sigma_{all}$ = allowable stress based on elastic stability, psi
$\sigma_B$ = drum shell longitudinal bending stress, psi
$\sigma_C$ = drum shell circumferential crushing stress, psi
$\sigma_{comb}$ = combined drum shell stresses, psi
$\sigma_{cr}$ = critical buckling stress, psi
$\sigma'_{cr}$ = elastic critical buckling stress, psi
$\sigma_{ult}$ = minimum ultimate strength of the material, psi
$\sigma_y$ = minimum yield stress of the material, psi

**5411.6 Drum (Types II and III Cranes).** The size, construction, and grooving for Types II and III crane drums shall be established in accordance with the provisions of CMAA 70.

**5411.7 Single-Failure-Proof Features (Type I Cranes)** (15)

*(a)* Single-failure-proof features are not required for the drum shell.

*(b)* In the event of failure of a drum shaft or bearing, the drum shall be retained on the trolley in a manner that precludes disengagement of any gearing or brake acting on the drum and precludes disablement of the load-retaining function of these components.

**5411.8 Single-Failure-Proof Features (Types II and III Cranes).** Single-failure-proof features are not required for the drum.

### 5412 Drive Motors

**5412.1 Type I Cranes.** Each hoist drive system, such as those indicated in Figs. 5416.1-1 through 5416.1-3, shall be provided with a hoist drive motor(s) for lifting and lowering loads. Motors shall be selected per para. 6470. Motor fasteners shall be per para. 5456.

**5412.2 Types II and III Cranes.** Motors shall be selected per para. 6470.

### 5413 Gearing

**5413.1 Type I Cranes.** Gearing shall be designed and manufactured in accordance with the procedures presented by the American Gear Manufacturers Association (AGMA) as modified by this Section. The gearing shall be designed for strength, durability, and momentary overload which includes the loads imposed during a seismic excursion.

Unless positive control of accurate alignment under varying loads can be ensured, parallel shaft gearing, both enclosed and open, shall be straddle mounted; that is, each shaft shall be supported by two outboard bearings. (The intent is to preclude inadequately supported or inaccurately aligned overhung gears or pinions, shafts with three bearing supports, and combination gear reducer/wire rope drum shafts.)

*(a) Allowable Strength Horsepower, $P_{at}$.* For helical and spur gears, AGMA 2001-C95 (Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth) applies. The allowable strength horsepower calculated must be greater than the horsepower required to lift the rated load at rated speed in hoisting applications.

$$P_{at} = \left(\frac{n_p d}{126{,}000\ K_v}\right)\left(\frac{F s_{at} J}{K_m P_d S_{fs} K_B}\right) \quad (8)$$

where

$d$ = operating pitch diameter of pinion, in.
$F$ = net face width of the narrowest member of the mating gears, in.
$J$ = geometry factor for bending strength
$K_B$ = rim thickness factor
$K_m$ = load distribution factor, para. 5413.1(f)
$K_v$ = dynamic factor
$n_p$ = pinion speed, rpm
$P_{at}$ = allowable transmitted power for bending strength, hp
$P_d$ = transverse diametral pitch, in.$^{-1}$
$S_{fs}$ = crane class factor (strength)
$s_{at}$ = allowable bending stress number for material, psi (strength)

Values for $K_v$, $J$, $K_B$, and $s_{at}$ can be determined from tables and curves in AGMA 2001-C95.

*(1) Crane Class Factor, $S_{fs}$.* The crane class factor is defined in CMAA 70. For Type I cranes, $S_{fs}$ = 1.05. For Types II and III cranes, use factors defined in CMAA 70.

*(b) Allowable Durability Horsepower, $P_{ac}$.* For helical and spur gears, AGMA 2001-C95 applies. The allowable durability horsepower calculated must be greater than the rated motor horsepower, considering efficiency in travel drive applications, and must be greater than the horsepower required to lift the rated load in hoisting applications.

$$P_{ac} = \left(\frac{n_p F I}{126{,}000\ K_v K_m S_{fd}}\right)\left(\frac{s_{ac} d C_H}{C_p}\right)^2 \quad (9)$$

where

$C_H$ = hardness ratio factor for pitting resistance
$C_p$ = elastic coefficient, (psi)$^{1/2}$
$d$ = operating pitch diameter of pinion, in.
$F$ = net face width of narrowest member of the mating gears, in.
$I$ = geometry factor for pitting resistance
$K_m$ = load distribution factor, para. 5413.1(f)
$K_v$ = dynamic factor
$n_p$ = pinion speed, rpm
$P_{ac}$ = allowable transmitted power for pitting resistance, hp
$S_{fd}$ = crane class factor (durability), para. 5413.1(d)
$s_{ac}$ = allowable contact stress number for material, psi

Values for $K_v$, $C_H$, $C_p$, $I$, and $s_{ac}$ can be determined from tables and curves in AGMA 2001-C95.

*(c) Allowable Momentary Overload Tooth Load, $W_{tov}$.* Allowable momentary overload tangential tooth load shall be greater than the maximum applied tangential tooth load considering stalled motor torque or seismic hook load.

For the purpose of this section, the allowable load in pounds can be written as

$$W_{tov} = \frac{1.6 F J s_{ay}}{1.1 P_d} \quad (10)$$

where

$F$ = net face width of narrowest member of the mating gears, in.
$J$ = geometry factor for bending strength
$P_d$ = transverse diametral pitch, in.$^{-1}$
$s_{ay}$ = allowable yield stress number for material, psi
$W_{tov}$ = allowable momentary overload, lb

*(d)* Crane Class Factor, $S_{fd}$ (durability), shall be as follows:

*(1) Hoist*

$$S_{fd} = (1.16)\,\frac{2(\text{rated load}) + 3(\text{lower block weight})}{3(\text{rated load} + \text{lower block weight})} \quad (11)$$

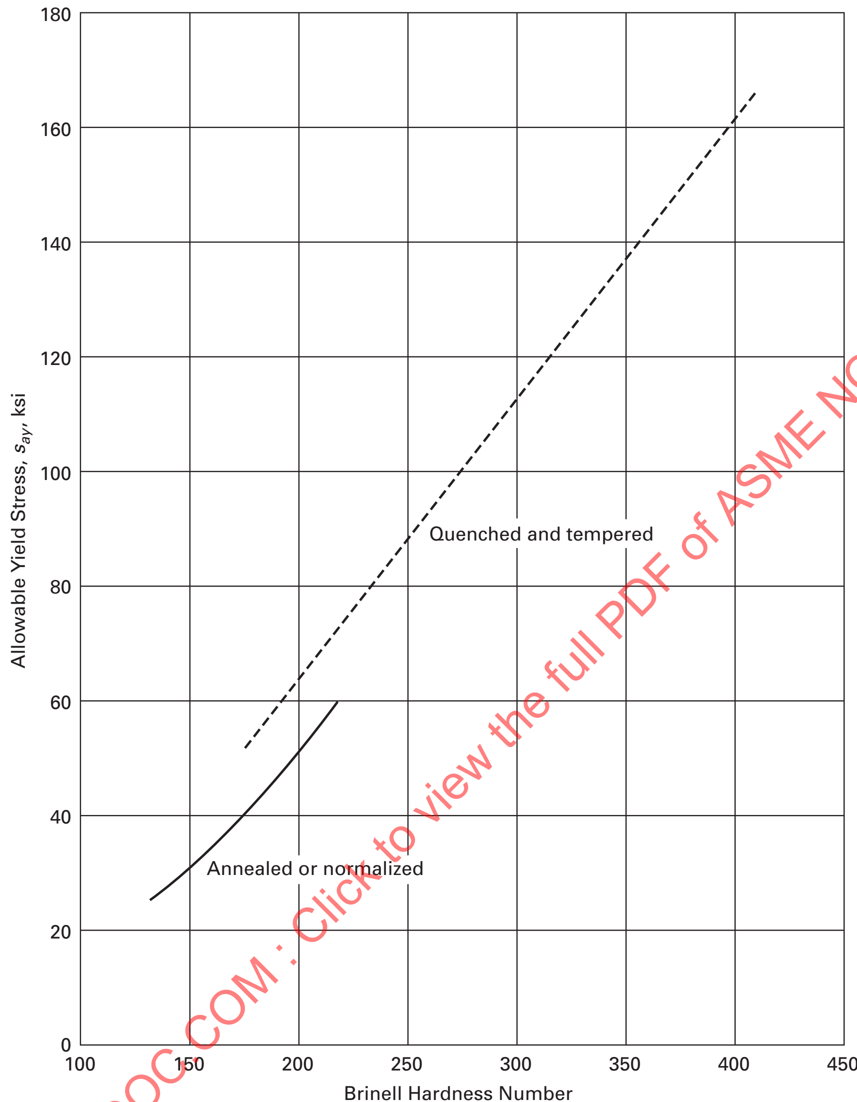
*(2) Trolley*

$$S_{fd} = (1.16)\,\frac{2(\text{rated load}) + 3(\text{trolley weight})}{3(\text{rated load} + \text{trolley weight})} \quad (12)$$

*(3) Bridge*

$$S_{fd} = (1.16)\,\frac{2(\text{rated load}) + 3(\text{trolley weight} + \text{bridge weight})}{3(\text{rated load} + \text{trolley weight} + \text{bridge weight})} \quad (13)$$

**Fig. 5413.1-1 Allowable Yield Stress, $s_{ay}$**






*(e) Allowable Stresses, $s_{at}$, $s_{ac}$, and $s_{ay}$*

*(1)* The allowable stress for gear material varies with material quality, heat treatment, forging practices, and material composition. Higher allowable stress values may be permitted in some cases by careful gear design, manufacturing procedure, and various surface treatments, such as surface peening.

*(2)* The allowable design fatigue stress, $s_{at}$, the allowable contact stress number, $s_{ac}$, and the allowable yield stress, $s_{ay}$, are shown in Table 5413.1-1 (see also Fig. 5413.1-1). When the gear is subjected to infrequent momentary high overloads, the maximum allowable stress is determined by the allowable yield properties rather than the fatigue strength of the material.

*(3)* The allowable design bending stress and contact stress numbers are based on 10 million cycles of load application as defined by AGMA. If the life is to be varied, refer to the life factor as defined in the AGMA standards.

*(f) Load Distribution Factor.* The load distribution factor depends upon the combined effects of

*(1)* misalignment of axis of rotation due to machining errors and bearing clearances

*(2)* lead deviations

*(3)* elastic deflections of shafts, bearings, and housing due to load

The following equation should be used to determine the load distribution factor, $K_m$ (see Table 5413.1-2), except where test data may support the application of other factors:

$$K_m = 0.03F + R \tag{14}$$

**Table 5413.1-1 Gearing Allowable Stresses**

| Heat Treatment | Minimum Material Hardness | $s_{at}$ | $s_{ac}$ | $s_{ay}$ |
|---|---|---|---|---|
| Through-hardened | 180 BHN | 24,500 | 85,000–95,000 | See Fig. 5413.1-1 |
| | 240 BHN | 30,000 | 105,000–115,000 | |
| | 300 BHN | 36,000 | 120,000–135,000 | |
| | 360 BHN | 40,000 | 145,000–160,000 | |
| | 440 BHN | 43,500 | 160,000–170,000 | |
| Induction or flame-hardened (full root hardness) | 50 RC | 45,000 | 170,000 | . . . |
| | 55 RC | 55,000 | 190,000 | . . . |
| Induction or flame-hardened (root not hardened) | 50 RC | 22,000 | 170,000 | . . . |
| | 55 RC | 22,000 | 190,000 | . . . |
| Case carburized | 55 RC | 55,000 | 200,000 | . . . |
| | 60 RC | 60,000 | 210,000 | . . . |
| | 65 RC | 65,000 | 220,000 | . . . |

**Table 5413.1-2 Load Distribution *R* Factors**

| Gearing Quality Description | Precision Quality | High Quality | High Quality [Note (1)] | Minimum Quality |
|---|---|---|---|---|
| Minimum AGMA quality number | 10–9 | 8 | 8 | 5–6 |
| Minimum percent no-load face contact | 90 | 75 | 60 | 50 |
| Minimum percent full-load face contact | 100 | 90 | 75 | 60 |
| *R* factor [Note (2)] | 1.07 | 1.24 | 1.54 | 1.84 |

NOTES:
(1) Quality of gearing being reduced due to heat treatment after cutting.
(2) Reference — AGMA standard.



where

$F$ = net face width of narrowest member of the mating gears, in.

$K_m$ = load distribution factor

$R$ = load distribution $R$ factor (see Table 5413.1-2)

*(g) Gear Efficiencies.* For the purpose of horsepower calculations, gear set efficiencies with anti-friction bearings for hoist, bridge, and trolley drives using spur or helical gearing shall be assumed as 0.97 for oil lubricated gear sets, and 0.95 for grease lubricated gear sets.

The efficiency of the gear train shall be established as

$$E = (0.97)^N \text{ (oil lubricated)}$$

$$E = (0.95)^N \text{ (grease lubricated)} \qquad (15)$$

where

$N$ = number of gear reductions

Efficiencies of other forms of gearing, such as herringbone, worm, and bevel, shall be per the gear reducer manufacturer's recommendations.

*(h) Gearing Forms and Quality.* Gearing forms, other than spur or helical, shall be designed in accordance with applicable procedures presented in AGMA standards and shall be machined from forged steel blanks or rounds of certified ASTM quality.

Machining tolerance, backlash, and the inspection of gearing shall conform to the latest AGMA standards.

Spur and helical gearing shall be hobbed to conform to a minimum AGMA quality number 8. In cases where heat treatment is done after cutting, consideration should be given to the effect of load distribution, $K_m$. Distortion due to heat treatment can result in gear quality being reduced from 8 to 5. Surface grind, which maintains the profile, would be required to use the factors defined in Table 5413.1-2, under High Quality.

*(i) Lubrication.* Lubricants for gear and bearings enclosed in gear drives and gear motor drives shall be in accordance with the practices of AGMA 9005-E02, Industrial Gear Lubrication, or as recommended by the gear manufacturer.

Lubrication for bearings used that are not enclosed in speed reducers and gear motor drives shall be in accordance with the bearing manufacturer's recommendation.

Enclosed gears shall comply with the following:

*(1)* shall have an oil pump when vertical gearing exceeds two reductions

*(2)* shall have sufficient heat radiation area to maintain lubricant at temperatures below maximum operating temperature

*(3)* shall have fill and drain connections, lubricant level indicator, and piping, and shall be piped to an accessible area on the crane

See para. 5460 for all general lubrication requirements.

**5413.2 Types II and III Cranes.** Gearing for Types II and III cranes shall be established in accordance with provisions in CMAA 70.

### 5414 Brakes — Load and Holding

**5414.1 Hoist Control Braking Means (Types I, II, and III Hoists).** An electrical control braking means or a mechanical braking means capable of maintaining controlled lowering speeds shall be provided. Electrically controlled braking means include regenerative, dynamic, countertorque, and eddy current. Brake sizing and design are specified in para. 6400.

Mechanical load brakes, if used as the control braking means, shall be provided with sufficient thermal capacity to accommodate lowering of the rated load at full speed through the expected operating distance.

**5414.2 Hoist Holding Brakes (Type I Hoists).** Two or more holding brakes shall be provided in accordance with para. 6422.1(a) such that after failure of any hoist shaft or coupling, one or more brakes remain capable of stopping and holding the rated load. Under normal operating conditions, the brakes shall apply automatically on power removal. The application of the second (and any other additional) brake(s) shall be delayed to minimize shock to the hoist drive train.

**5414.3 Hoist Holding Brakes (Types II and III Hoists).** Hoist holding brakes shall be selected in accordance with para. 6420.

### 5415 Load Combinations — Hoist Drive Shafting (Types I, II, and III Cranes)

**5415.1 Load Combinations, Allowable Stresses, and Service Factors.** The hoist drive machinery shafting shall be designed to resist the following load combinations with corresponding values of allowable stresses and service factors. Combinations of the various types of loading are shown in Table 5415.1-1.

**5415.2 Computation — Analysis.** Analytical stress computations shall be performed according to procedures in para. 5470.

### 5416 Single-Failure-Proof Features

**5416.1 Type I Cranes.** The hoist machinery arrangement shall be designed to provide assurance that a failure of a single hoist component would not result in the loss of the lifted load or, in some cases, unwanted movement of the load. This can be accomplished in several ways. Typical applications of hoist machinery arrangements are illustrated in Figs. 5416.1-1, 5416.1-2, and 5416.1-3, and are defined below.

*(a) Typical Hoist Machinery Arrangement With Emergency Brake.* A typical hoist machinery arrangement with emergency brake includes one gear reducer with a single drive motor, with two holding brakes and one emergency brake. One of the holding brakes acts as a primary brake; the other holding brake acts as a backup with a delayed setting. The emergency brake is located on the drum; it is intended to set in an emergency in case of a component malfunction or failure in the hoist load path. This machinery arrangement is used where a load drop during a hoist emergency (single component failure) must be prevented.

*(b) Typical Hoist Machinery Arrangement With Redundant Gear Reducers and Brakes.* The typical hoist machinery arrangement with redundant gear reducers includes one drive motor connected by high speed shaft to two separate gear reducers and two holding brakes. One of the holding brakes acts as a primary brake; the other holding brake acts as a backup with a delayed setting. At least two brakes shall be available for emergency load lowering following a single hoist drive train failure. Each gear train shall be sized for the total full-load drive torque of the motor.

*(c) Typical Redundant-Hoist Machinery Arrangement.* The typical redundant-hoist machinery arrangement combines two hoists into one redundant hoist. This arrangement includes wire rope from the two hoist drums independently reeved into a common load block. Each hoist provides its own load path between the load block and holding brake. Each redundant hoist shall be sized such that, following a failure of one hoist load path component, the redundant hoist provides the capability to stop and hold the load.

**5416.2 Types II and III Cranes.** Single-failure-proof features are not required.

### 5420 Reeving System

*(a) Type I Cranes.* The design of the rope reeving system shall be such that a single rope failure will not result in the loss of the lifted load. A load balance shall be provided on each rope system. In the event of a hook overtravel, where the lower block contacts the crane structure, the ropes shall not be cut or crushed.

The wire rope and fleet angle requirements shall be in accordance with paras. 5425.1 and 5426, respectively.

### Table 5415.1-1 Load Combinations — Hoist Drive Shafting (15)

| Crane Type | Load Combinations | Type of Loading [Note (1)]: Live Load | Dead Load | Impact | Inertia | Seismic | Load Hang-Up | Motor Torque | Allowable Stresses | Service Factor Minimum |
|---|---|---|---|---|---|---|---|---|---|---|
| Type I hoist | 1 | X(R) | X | X | . . . | . . . | . . . | . . . | Fatigue | 1.0 |
| | 2 | X(R) | X | . . . | X | . . . | . . . | . . . | Fatigue | 1.0 |
| | 3 | . . . | . . . | . . . | . . . | . . . | . . . | X | Fatigue | 1.0 |
| | 4 [Note (2)] | . . . | . . . | . . . | X | . . . | X | . . . | $0.75\sigma_y$ [Note (3)] | 0.5 [Note (4)] |
| | 5 [Note (2)] | X(C) | . . . | . . . | . . . | X | . . . | . . . | $0.75\sigma_y$ [Note (3)] | 0.5 [Note (4)] |
| Types II and III hoists | | | | | | Per CMAA 70 | | | | |

NOTES:
(1) Type of loading:
Live load: critical (C) or rated (R) load.
Dead load: load block and attachments.
Impact: operational.
Inertia: rotation and linear.
Seismic: earthquake condition (refer to para. 4140).
Load hang-up: motor pull-out torque and rotational inertia. (For design computations, 275% of motor nameplate rating shall be used. In cases of higher values than the 275% motor nameplate rating, the ratio of the actual value of percent rated motor torque divided by 275% shall be considered in relation to the calculated service factor.)
Motor torque: nameplate rating.
(2) Calculated stresses for load combinations 4 and 5 are based on the nominal cross section, whereas stress concentration factors need not be included.
(3) $\sigma_y$ = minimum yield stress of material
(4) Components that are not dual or redundant shall be designed with a service factor of 1.0.



*(1) Single-Failure-Proof Features.* Single-failure-proof mechanical features for the reeving system shall consist of the following:

*(-a)* Reeving system shall be divided into two separate load paths so that either path will support the load and maintain vertical alignment in the event of rope breakage or failure in the rope system. Figure 5420-1 shows one such reeving system. Other reeving systems that meet the above requirements are acceptable.

*(-b)* Upper blocks and load blocks shall be designed such that each attaching point will be able to support three times the maximum critical load without permanent deformation of any part of the block assembly. These assemblies shall be designed so that the sheaves will be contained in the event of failure of the sheave support pin.

*(-c)* Reverse bends of the rope shall only be permitted between the ropes threading off the drum and the lower block.

*(b) Types II and III Cranes.* Reeving system components for Types II and III cranes shall be in accordance with CMAA 70. Hoist reeving may be either single or double and may be one or multiple parts.

*(1)* On single-reeved hoists, one end of the rope is attached to the drum and the other end is dead ended on a stationary portion of the hoist. Continuous drum grooving runs in one direction. The load block moves laterally in the direction of the axis of the drum as the rope winds onto or off of the drum. Refer to Fig. 5420-2, illustration (a).

*(2)* On double-reeved hoists, both ends of the rope are attached to the drum. The drum is grooved with left and right grooves beginning at both ends of the drum, then grooving toward the center of the drum. The load block will follow a true vertical path (true vertical lift) as the ropes wind toward or away from each other onto or off the drum. Refer to Fig. 5420-2, illustration (b).

*(3)* Single-failure-proof features are not required for Types II and III cranes.

## 5421 Upper Block

### 5421.1 Type I Cranes

*(a)* The upper block, in conjunction with the load block, shall be designed to maintain a vertical load balance about the center of the lifted load and shall have a reeving system of dual design.

*(b)* All design loads and allowable stresses for mechanical and structural components of the upper block shall be in accordance with paras. 5300 and 4310, respectively. The upper block shall be accessible from above the trolley floor.

**5421.2 Types II and III Cranes.** Upper blocks for Types II and III cranes shall be established in accordance with the provisions of CMAA 70.

**Fig. 5416.1-1 Typical Hoist Machinery Arrangement With Emergency Brake**

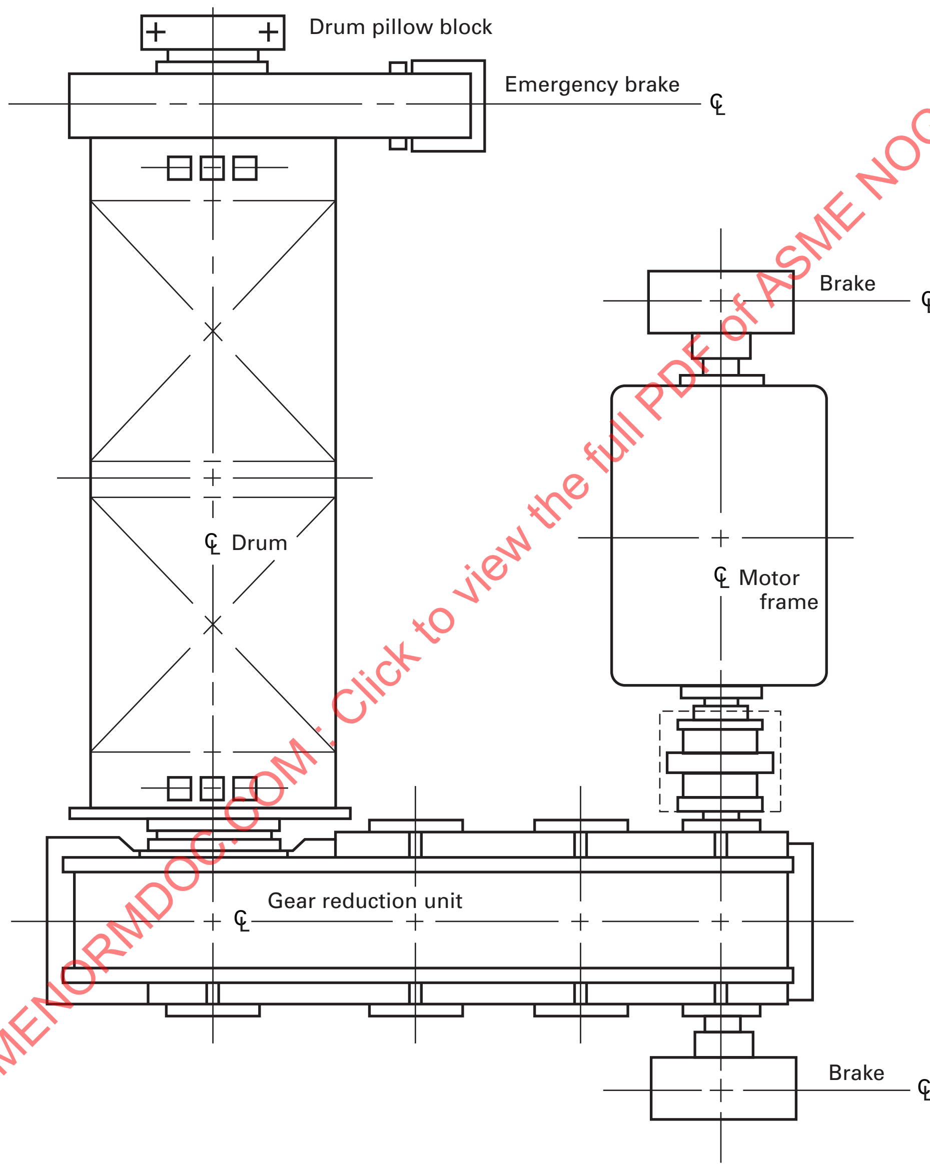


**Fig. 5416.1-2 Typical Hoist Machinery Arrangement With Redundant Gear Reducers and Brakes**

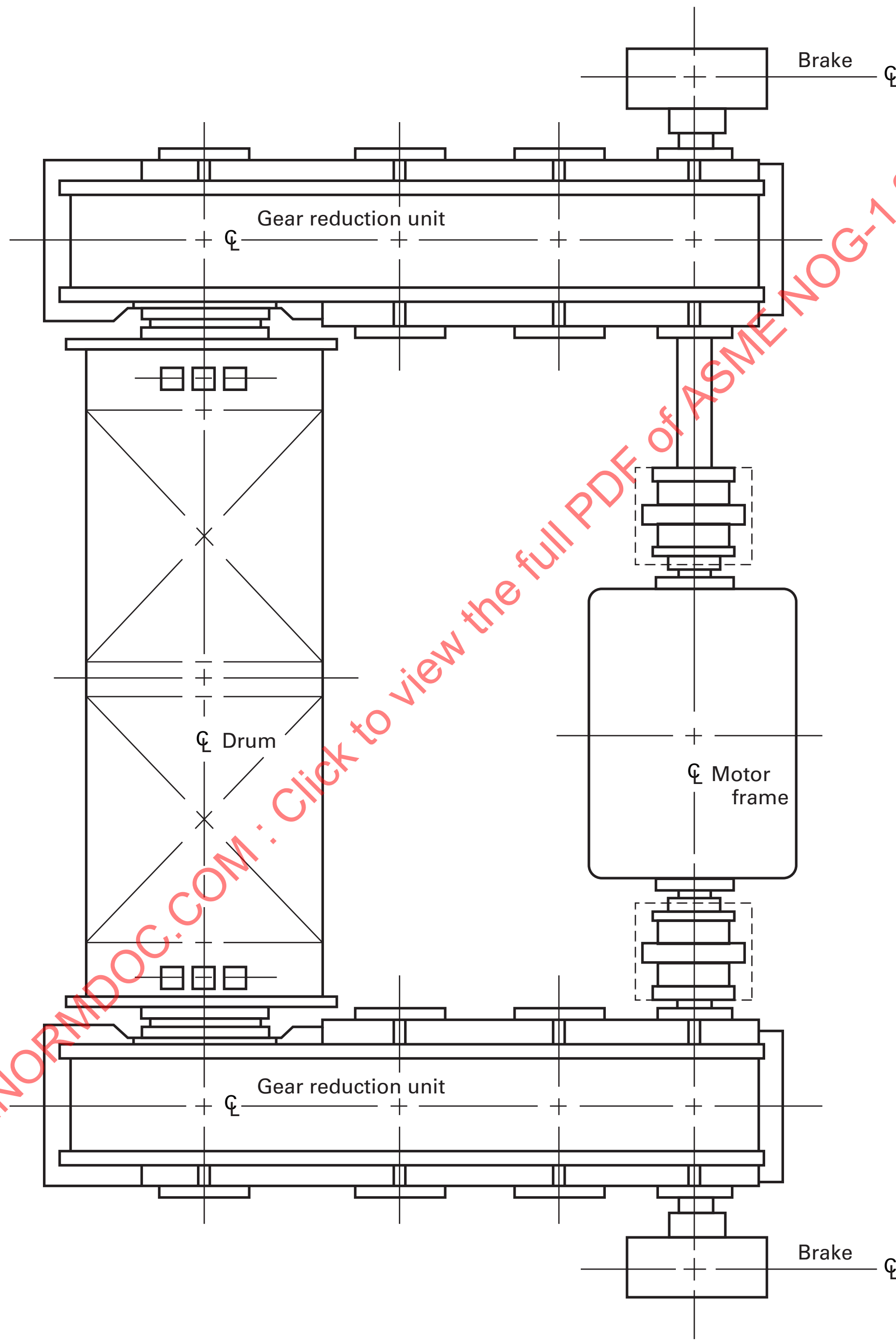


**Fig. 5416.1-3 Typical Redundant-Hoist Machinery Arrangement**

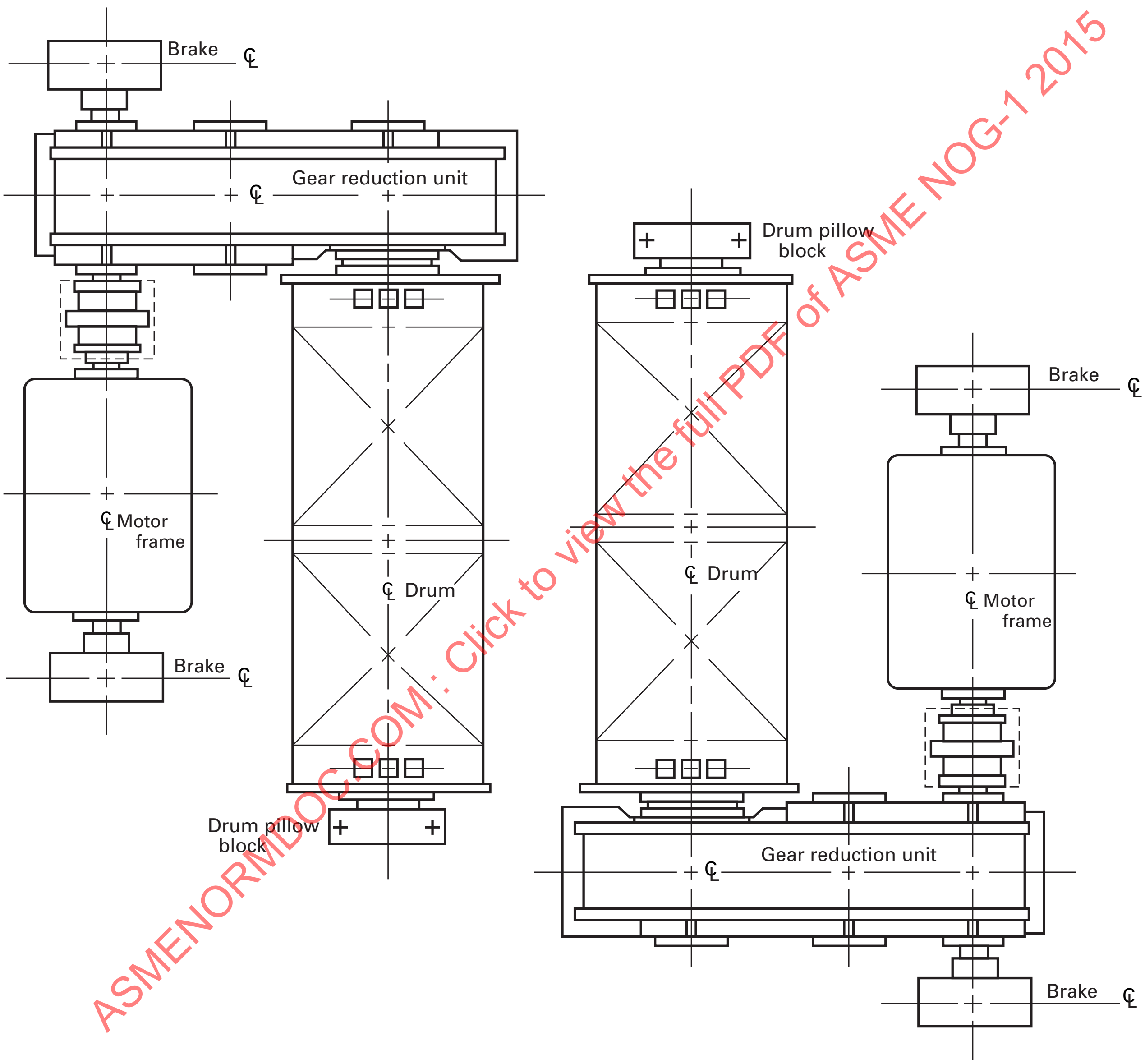
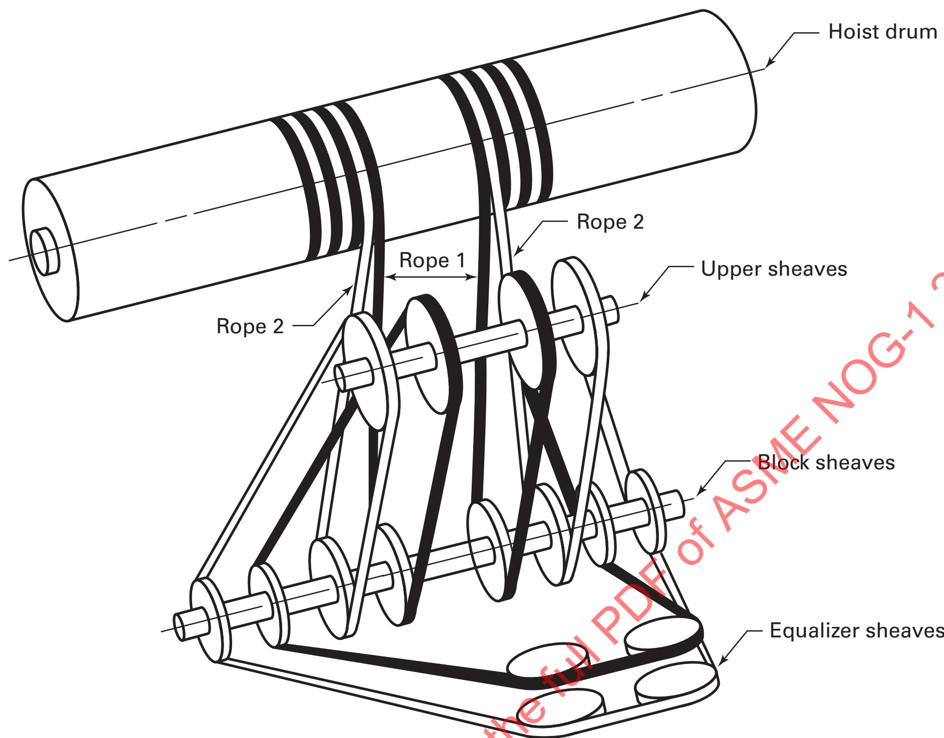


**Fig. 5420-1 Single-Failure-Proof Reeving Example**




GENERAL NOTES:
(a) Relative position of sheaves is extended and angle of view is distorted to clarify reeving paths.
(b) Number of parts of reeving may vary.



### 5422 Load Block

#### 5422.1 Type I Cranes

*(a)* The load block frame shall be constructed of rolled steel and shall be entirely enclosed except for the rope openings. The hook(s) shall be free to swivel on antifriction or sleeve bearing so constructed as to exclude dirt and also shall be provided with a means for lubrication. Refer to para. 5460 for data relating to lubrication.

*(b)* Welding of trunnions for critical load handling load blocks shall not be permitted.

*(c)* Load block assembly components, including hook, hook nut, trunnion, and load block structure, shall meet one of the following criteria:

*(1)* dual load paths, para. 5428.1(a)

*(2)* double design factor, para. 5428.1(b)

**5422.2 Types II and III Cranes.** Load blocks for Types II and III cranes shall be established in accordance with the provisions of CMAA 70.

### 5423 Equalizer Systems

(15) **5423.1 Type I Cranes**

*(a)* Where separate rope equalizing is required, either an equalizer bar or a sheave will be acceptable. In either case, two separate and complete reeving systems shall be provided. The equalizer, where possible, should be designed to be accessible from the floor of the trolley and be made in such a manner that it can turn or swivel to align itself with the pull of the ropes.

*(b)* Equalizer sheaves, when used, shall have a pitch diameter not less than one-half of the diameter of the running sheaves.

*(c)* Rope equalizer systems shall be designed to meet the criteria as delineated herein.

*(1)* Reeving equalization shall not be restricted under normal operating conditions.

*(2)* Adequate free movement to compensate for operational block swing and/or normal rope stretch shall be provided.

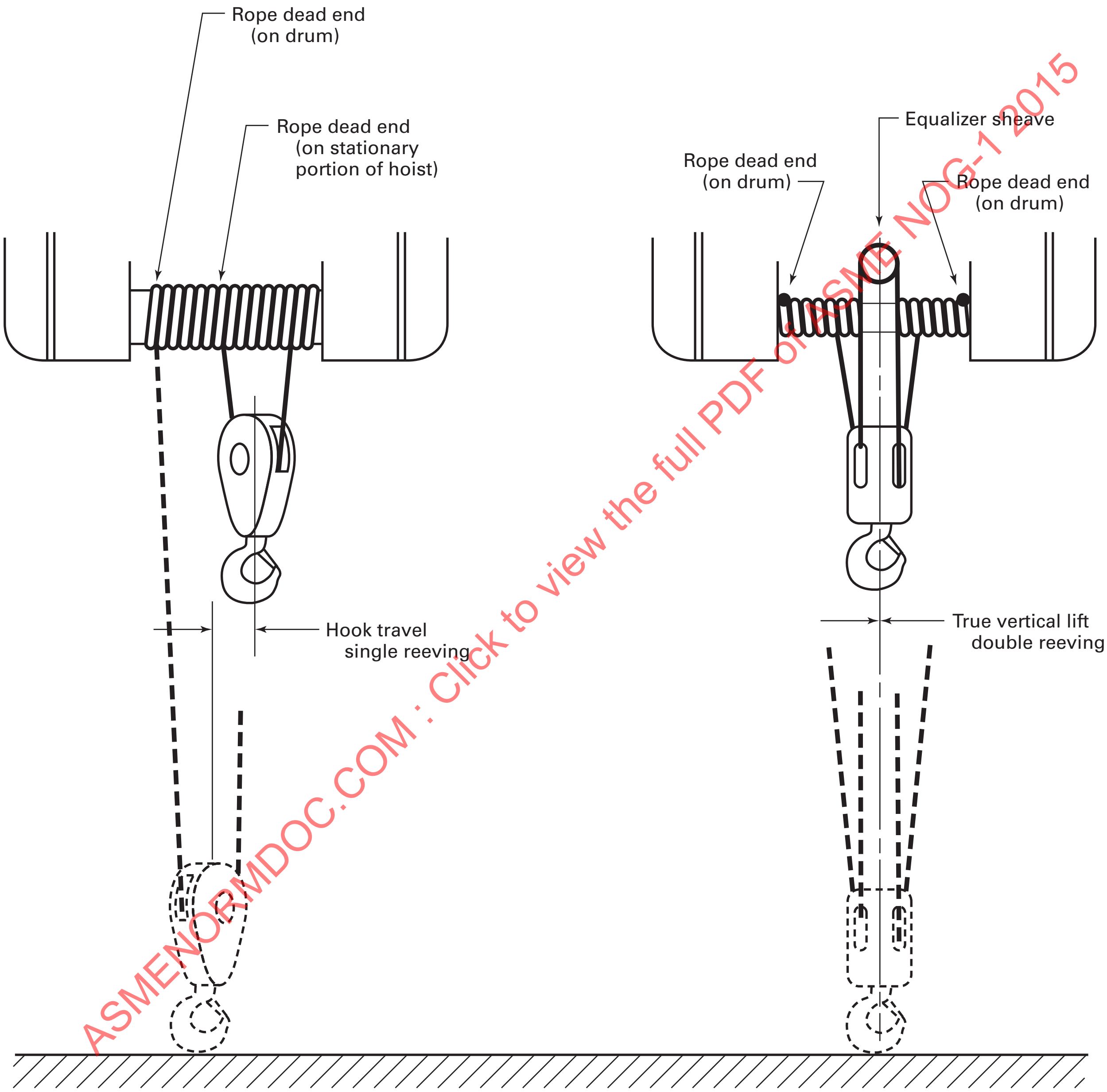
*(3)* Sensing and automatic signaling of excessive rope displacement to either side shall be provided.

*(4)* Sensing and automatic signaling of a broken reeving shall be provided.

*(5)* In the event of a broken rope, the remaining intact reeving system shall not be loaded to more than 40% of the breaking strength of the wire rope, including the dynamic effects of the load transfer.

*(6)* The vertical displacement of the load following a rope failure shall be minimized.

**Fig. 5420-2 Single and Double Reeving**




(a) Single Reeving

(b) Double Reeving

(7) The vertical displacement of the load following a rope failure shall be calculated and reported to the purchaser.

(8) The effects of a broken rope on the entire system including the equalizer assembly shall be analyzed.

(9) The sheave equalizer system or equalizer bar system shall be contained in the event of a single failure. Alternatively, to preclude component failure as a credible event, equalizer system components may be designed with double the normal design factors.

**5423.2 Types II and III Cranes.** Equalizer bars or sheaves of Types II and III cranes shall be established in accordance with the provisions of CMAA 70.

### 5424 Sheave Pins

#### 5424.1 Type I Cranes

(a) Sheave pins for the upper block and load block shall be designed to withstand the combined line pull of the live load, plus the dead load of the load block.

(b) Seismic effects shall be included in the analysis.

(c) Analytical stress computation shall be performed in accordance with para. 5470.

(d) Service factors shall be applied in accordance with para. 5320.

(e) Grease lubricated sheave bearings should be provided with individual lubrication fittings if the pin size is sufficiently large to provide the space for these fittings.

**5424.2 Types II and III Cranes.** Sheave pins for Types II and III cranes shall be in accordance with the provisions of CMAA 70.

### 5425 Rope Construction, Loads, and Design Factors

#### 5425.1 Type I Cranes

(a) *Rope Construction.* The hoist rope shall be of a construction for crane service, such as improved or extra-improved plow steel grades, 6 × 37 class construction (6 strand, 27 to 49 wires per strand), right regular lay with independent wire rope core. Other materials, strength grades, rope constructions, type of cores, and lay may be used where application or future development in wire rope technology indicates.

(b) *Selection of Ropes.* Hoisting ropes shall be selected based on the more stringent of the following requirements:

(1) The rated load (without impact), plus the weight of the load block divided by the total number of parts of rope per system, shall not exceed 20% of the manufacturer's published breaking strength.

(2) The maximum critical load (without impact), plus the weight of the load block divided by the total number of parts of rope, shall not exceed 10% of the manufacturer's published breaking strength on the total system or 20% on each of the dual systems.

(3) The impact load in the transfer of the maximum critical load from one of the dual hoisting rope systems to the other, in the event of rope failure, shall not exceed 40% of the manufacturer's published breaking strength.

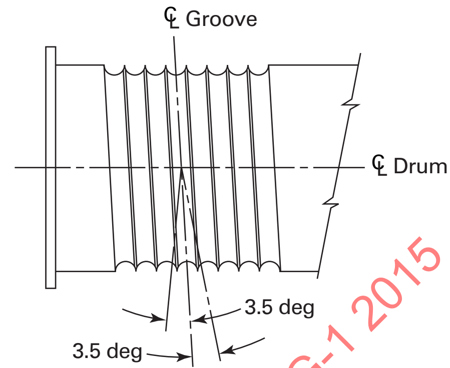
(4) The seismic load (para. 4130) with all parts of rope intact shall not exceed 40% of the manufacturer's published breaking strength.

(5) The load resulting from the maximum possible overload of the hoisting machinery or crane, including two-blocking and load hangup, shall not exceed 40% of the manufacturer's published breaking strength.

(c) *Breaking Strength of Ropes.* The breaking strength of rope shall conform to the manufacturer's published values based upon the minimum values determined by actual tensile tests performed on new ropes. The theoretical strengths based upon material properties and net metal cross-section shall not be used.

**5425.2 Types II and III Cranes.** Rope construction, loads, and design factors for Types II and III cranes shall be established in accordance with the provisions of CMAA 70.

**Fig. 5426.1-1 Drum Fleet Angle**




### 5426 Fleet Angles

#### 5426.1 Type I Cranes

(a) The rope fleet angle to the drum grooves shall be limited to $3\frac{1}{2}$ deg, except at the last 3 ft of the maximum lift elevation it shall be limited to 4 deg. Refer to Fig. 5426.1-1 for fleet angle measurement to the drum groove.

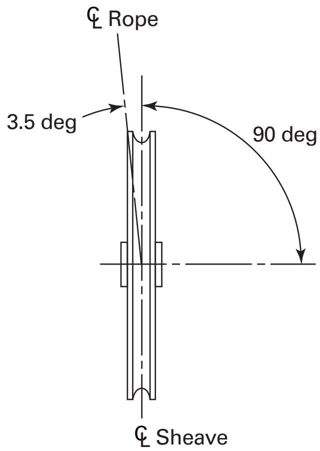
(b) The rope fleet angle for sheaves shall be limited to $3\frac{1}{2}$ deg, except at the last 3 ft of the maximum lift elevation it shall be limited to $4\frac{1}{2}$ deg. Refer to Fig. 5426.1-2 for fleet angle measurement to the sheaves.

**5426.2 Types II and III Cranes.** The operating fleet angle for Types II and III cranes shall be in accordance with CMAA 70.

### 5427 Sheaves

**5427.1 Type I Cranes.** Sheaves shall be of steel and provided with antifriction or sleeve bearings. Proper provision for the effects of thrust shall be made where (15)

Fig. 5426.1-2 Sheave Fleet Angle




applicable. Figures 5427.1-1 and 5427.1-2 depict recommended dimensions for running sheaves. The pitch diameter for running sheaves shall be not less than 24 times the diameter of the hoist rope for 6 × 37 classes of rope construction and not less than 30 times the hoist rope diameter for 6 × 19 rope construction classes. Pitch diameter of nonrunning (equalizer) sheaves shall not be less than half the diameter of the running sheaves.

Sheave journals requiring external lubrication shall be provided with individual grease lines, with the fittings located such that they will be protected from damage (see para. 5460). Means shall be provided to prevent the wire rope from leaving the sheave grooves.

**5427.2 Types II and III Cranes.** Sheaves for Types II and III cranes shall be established in accordance with the provisions of CMAA 70.

### 5428 Hooks

**5428.1 Single-Failure-Proof Features (Type I Cranes).** Type I cranes shall be provided with hooks (hook) that either

*(a)* provide(s) two load-attaching points designed such that each attaching point provides a separate load path. Each load path shall be able to support three times the maximum critical load without permanent deformation of the hook, other than localized strain concentration in the area for which additional material has been provided for wear, or

*(b)* provide(s) one load-attaching point designed such that it provides a single load path. The single load path shall be able to support six times the maximum critical load without permanent deformation of the hook, other than localized strain concentration in the area for which additional material has been provided for wear.

**5428.2 Single-Failure-Proof Features (Types II and III Cranes).** Single-failure-proof mechanical features are not required.

**5428.3 Analytical Procedure for Curved Beams.** Hook stresses are calculated using the curved beam method described by A.M. Wahl in *The Journal of Applied Mechanics*, pp. A-239 to A-242, September 1946. For hook configuration and calculation procedures, see para. 5470.

**5428.4 Indication of Maximum Sling Angle on Sister Hooks (Types I, II, and III Hoists).** When sister hooks are provided, the maximum permitted included angle of the slings between the sister hook prongs shall be stamped on the hook.

**5429 Reeving Efficiency (Types I, II, and III Cranes).** The reeving efficiencies are based on the total number of ropes supporting one load block either double reeved or single reeved. The values of the reeving efficiencies are determined from eq. (16).

For the purpose of calculation for the overall mechanical efficiency of the hoist, the efficiencies of the gearing, rope, and drum shall be established as follows:

$$E = (E_g^n)\,(E_s^m)\,(E_d) \tag{16}$$

where

$E$ = overall combined efficiency

$E_g^n$ = combined efficiency of gear reductions and antifriction bearings

$n$ = number of gear reductions

The efficiency of a gear reduction mounted on antifriction bearings for hoist drives using spur, helical, or herringbone gearing shall be assumed to be 0.97. Efficiencies of other forms of gearing such as worm and bevel shall be per the gear reducer manufacturer's recommendation.

$E_s^m$ = combined efficiency of rope on sheaves

$m$ = total number of rotating sheaves divided by the number of ropes off drum

The efficiency of the rope operating on a sheave that is mounted on antifriction bearing(s) shall be assumed to be 0.99 for each rotating sheave between the drum and the equalizer.

$E_d$ = combined efficiency of ropes on drum and antifriction bearings

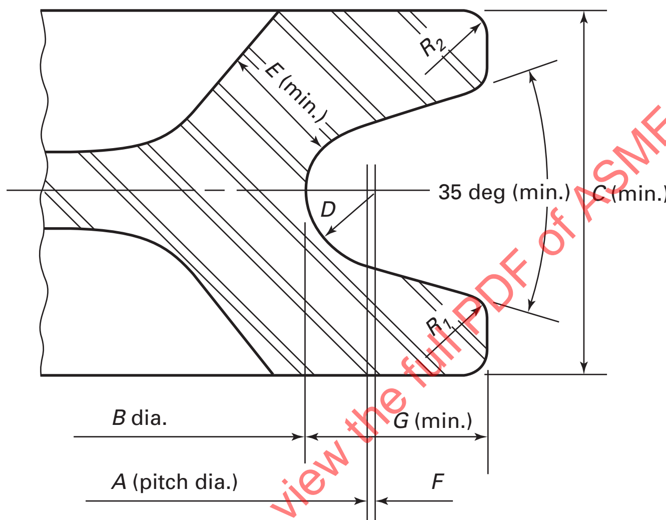
= 0.98 for two ropes off drum or 0.99 for one rope off drum

### 5430 Trolley Drives (15)

*(a) Type I Cranes.* Trolley drives shall consist of one of the following arrangements, which are shown in Fig. 5430-1. Each four-wheel trolley shall use a drive arrangement that provides drive to at least 50% of the wheels. Trolleys having more than four wheels shall have at least 25% of the wheels driven.

In trolley travel drives, single-failure-proof features are generally not required. However, in those cases where a failure of a component could result in a facility

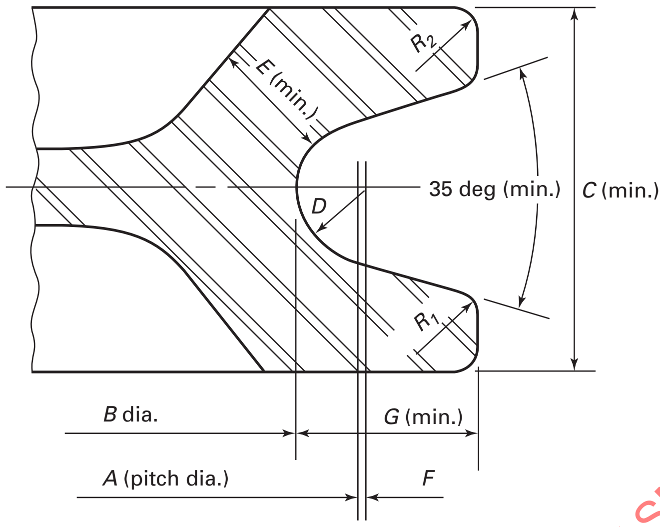
## Fig. 5427.1-1 Proportions for 24:1 Sheave-to-Rope Ratio (15)




| Sheave Wheel Contours | | | | | | | |
|---|---|---|---|---|---|---|---|
| Rope Dia., in. | *A* | *B* | *C* | *D* | *E* | *F* | *G* |
| 1/2 | 12 | 11 1/2 | 1 3/4 | 9/32 | 1/2 | 1/32 | 3/4 |
| 5/8 | 15 | 14 3/8 | 2 | 11/32 | 5/8 | 1/32 | 15/16 |
| 3/4 | 18 | 17 1/4 | 2 1/4 | 13/32 | 3/4 | 1/32 | 1 1/8 |
| 7/8 | 21 | 20 1/2 | 2 1/2 | 31/64 | 7/8 | 3/64 | 1 5/16 |
| 1 | 24 | 23 | 2 3/4 | 35/64 | 1 | 3/64 | 1 1/2 |
| 1 1/8 | 27 | 25 7/8 | 3 | 39/64 | 1 1/8 | 3/64 | 1 11/16 |
| 1 1/4 | 30 | 28 3/4 | 3 1/4 | 11/16 | 1 1/4 | 1/16 | 1 7/8 |
| 1 3/8 | 33 | 31 5/8 | 3 1/2 | 3/4 | 1 3/8 | 1/16 | 2 1/16 |
| 1 1/2 | 36 | 34 1/2 | 3 3/4 | 13/16 | 1 1/2 | 1/16 | 2 1/4 |

GENERAL NOTES:
(a) $R_1$ (min.) = the lesser of 25% rope diameter or 1/4 in.
(b) $R_2$ (min.) = 1/16 in.

(15) **Fig. 5427.1-2 Proportions for 30:1 Sheave-to-Rope Ratio**




| Sheave Wheel Contours | | | | | | | |
|---|---|---|---|---|---|---|---|
| Rope Dia., in. | *A* | *B* | *C* | *D* | *E* | *F* | *G* |
| 1/2 | 15 | 14 1/2 | 1 3/4 | 9/32 | 1/2 | 1/32 | 3/4 |
| 5/8 | 18 3/4 | 18 1/8 | 2 | 11/32 | 5/8 | 1/32 | 15/16 |
| 3/4 | 22 1/2 | 21 3/4 | 2 1/4 | 13/32 | 3/4 | 1/32 | 1 1/8 |
| 7/8 | 26 1/4 | 25 3/8 | 2 1/2 | 31/64 | 7/8 | 3/64 | 1 5/16 |
| 1 | 30 | 29 | 2 3/4 | 35/64 | 1 | 3/64 | 1 1/2 |
| 1 1/8 | 33 3/4 | 32 5/8 | 3 | 39/64 | 1 1/8 | 3/64 | 1 11/16 |
| 1 1/4 | 37 1/2 | 36 1/4 | 3 1/4 | 11/16 | 1 1/4 | 1/16 | 1 7/8 |
| 1 3/8 | 41 1/4 | 39 7/8 | 3 1/2 | 3/4 | 1 3/8 | 1/16 | 2 1/16 |
| 1 1/2 | 45 | 43 1/2 | 3 3/4 | 13/16 | 1 1/2 | 1/16 | 2 1/4 |

GENERAL NOTES:

(a) $R_1$ (min.) = the lesser of 25% rope diameter or 1/4 in.

(b) $R_2$ (min.) = 1/16 in.



unacceptable excursion, the design shall incorporate single-failure-proof features to ensure that the trolley can be brought to a safe stop.

*(1) A-1 Drive.* The motor is located near the center of the trolley and is connected by means of a flexible coupling to a self-contained gear reduction unit also located at the center of the trolley, which shall be connected to the line shaft by solid or half-flexible couplings. The line shaft is in turn connected to the trolley wheel axles by means of floating shafts with half-flexible couplings.

*(2) A-1A Drive.* Same as A-1 drive, except the self-contained gear reduction unit is located closer to one of the trolley wheel axles.

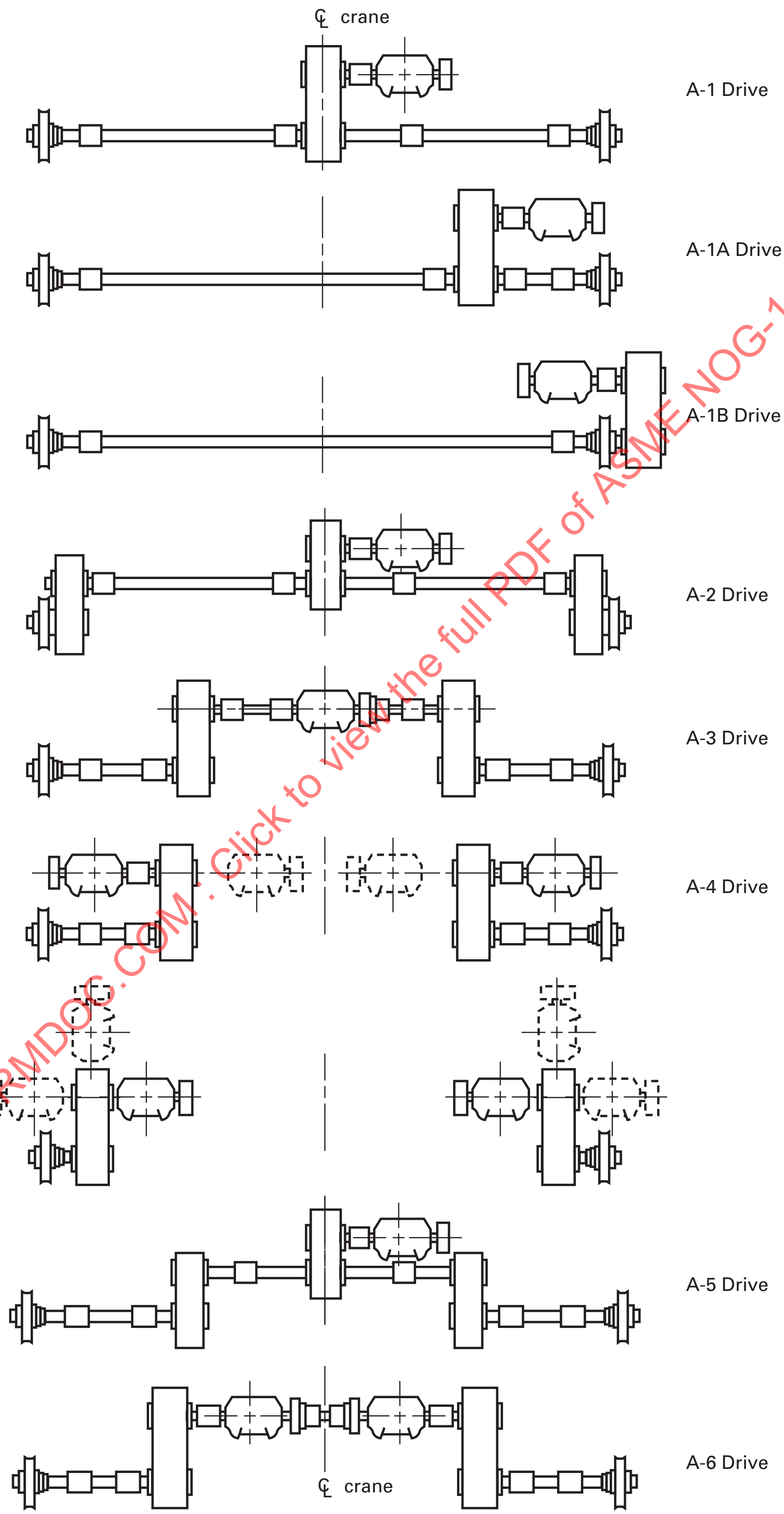
*(3) A-1B Drive.* Same as A-1 drive, except the self-contained gear reduction unit is located outside the trolley frame close to one of the trolley wheel axles.

*(4) A-2 Drive.* The motor is connected by means of a flexible coupling to a self-contained gear reduction unit located at the center of the trolley. The trolley wheels shall be driven through gears that are either pressed or keyed to their axles or which are attached directly to the wheel. Floating shaft couplings shall be half-flexible type at wheel and reducer connections. If splicing of floating shafts is required, couplings shall be of the solid type.

*(5) A-3 Drive.* The motor is located at the center of the trolley and is connected directly to the line shaft by half-flexible couplings. Self-contained gear reduction units located near each end of the trolley shall be connected to the trolley wheel axles by means of floating shafts with half-flexible couplings or directly with full-flexible couplings.

*(6) A-4 Drive.* The motors are located near each end of the trolley without torque shafts, and they shall be connected to self-contained gear reduction units. The gear reduction units shall be applied to the truck wheels by means of either suitable shafts with couplings or directly mounted to the wheel axle shaft extension. Another variation of this drive would separate the high-speed and final reductions by locating the motors near each end of the trolley without torque shafts. The motors

**Fig. 5430-1 Arrangement of Crane Trolley Drives** (15)



will be connected to self-contained, high-speed gear boxes with pinions mounted on the output shafts of the high-speed gear boxes that will drive the truck wheels through gears pressed and keyed on their axles or by gears fastened to the truck wheels.

*(7) A-5 Drive.* The motor is located near the center of the trolley and is connected by means of a flexible coupling to a self-contained gear reduction unit located near the center of the trolley. This reduction unit shall be connected by sections of line shaft having solid or half-flexible couplings to self-contained gear reduction units located near each end of the trolley, and these in turn connect to trolley wheel axles by means of floating shafts with half-flexible couplings or directly by means of full-flexible couplings.

*(8) A-6 Drive.* The motors are located near each end of the trolley and are connected with a torque shaft. On the drive end, the motors shall be connected to self-contained gear reduction units by means of flexible couplings. Gear reduction units are to be connected to trolley wheel axles by means of floating shafts with half-flexible couplings. High-speed shafts between motors shall be connected by means of half-flexible couplings. All other couplings shall be of the solid type.

*(b) Types II and III Cranes.* Arrangement of trolley drives is the same as for Type I cranes.

### 5431 Motors — Trolley

**5431.1 Type I Cranes.** Each motor in a trolley drive arrangement (refer to para. 5430) shall connect directly or indirectly to two opposite wheels for traversing the trolley, or, if individually driven wheels are used, a motor shall be provided to drive opposite wheels. Motors are to be selected per para. 6400.

**5431.2 Types II and III Cranes.** Trolley drive motors shall be selected in accordance with para. 6400.

### 5432 Trolley Travel Gearing

**5432.1 General — Type I Cranes.** Trolley travel gearing shall be designed in accordance with para. 5413 except for the areas delineated in this Section.

The actual horsepower imposed on the gearing shall be considered as the rated motor horsepower at its normal time rating as defined in Section 6000. If 60-min series wound motors are used, then special consideration shall be given to the short time torque ratings of such motors.

**5432.2 Types II and III Cranes.** Gearing for trolley travels shall be established in accordance with the provisions of CMAA 70.

### 5433 Trolley Brakes

**5433.1 Type I Cranes**

*(a) Service Brakes.* A trolley drive system shall be provided with a service braking means that may be satisfied by the emergency brake, a separate control brake, or as part of the motor controls. Service brake requirements, brake sizes, and brake designs are specified in Section 6000.

*(b) Emergency and Parking Brakes.* Each primary trolley drive motor shall be provided with an emergency and a parking brake. Brake sizing and design are specified in Section 6000.

**5433.2 Types II and III Cranes.** Trolley brakes shall be in accordance with CMAA 70.

### 5440 Bridge Drives (15)

*(a) Type I Cranes.* Bridge drives shall consist of one of the following arrangements, which are shown in Fig. 5440-1. Each four-wheel bridge shall use a drive arrangement that has at least 50% of the wheels driven. Bridges having more than four wheels, such as eight-wheel, twelve-wheel, or sixteen-wheel, shall have at least 25% of the wheels driven. Bridge drives shall be located directly opposite each other on rectilinear traveling overhead and gantry cranes [see Fig. 5440-1], and diagonally opposite on polar cranes [see Fig. 5440-2].

In bridge travel drives, single-failure-proof features are generally not required. However, in those cases where a failure of a component could result in a facility unacceptable excursion, the design shall incorporate single-failure-proof features to ensure that the bridge can be brought to a safe stop.

*(1) A-1 Drive.* The motor is located near the center of the bridge and is connected by means of a flexible coupling to a self-contained gear reduction unit also located at the center of the bridge, which shall be connected to the line shaft by solid or half-flexible couplings. The line shaft is in turn connected to the bridge wheel axles by means of floating shafts with half-flexible couplings [see (a)(7) below, Note].

*(2) A-2 Drive.* The motor is connected by means of a flexible coupling to a self-contained gear reduction unit located at the center of the bridge. The bridge wheels shall be driven through gears that are either press fitted or attached directly to the wheel. Line shaft couplings at the center reducer shall be either solid or half-flexible. Line shaft couplings at the truck reduction pinion shall be of the half-flexible type. All other couplings shall be of the solid type [see (a)(7) below, Note].

*(3) A-3 Drive.* The motor is located at the center of the bridge and is connected directly to the line shaft by means of half-flexible couplings. Self-contained gear reduction units located near each end of the bridge shall be connected to the bridge wheel axles by means of floating shafts with half-flexible couplings. All other couplings shall be of the solid type.

*(4) A-4 Drive.* The motors are located near each end of the bridge without torque shafts, and they shall be connected to self-contained gear reduction units. The gear reduction units shall be applied to the truck wheels

**Fig. 5440-1 Arrangement of Crane Bridge Drives** (15)

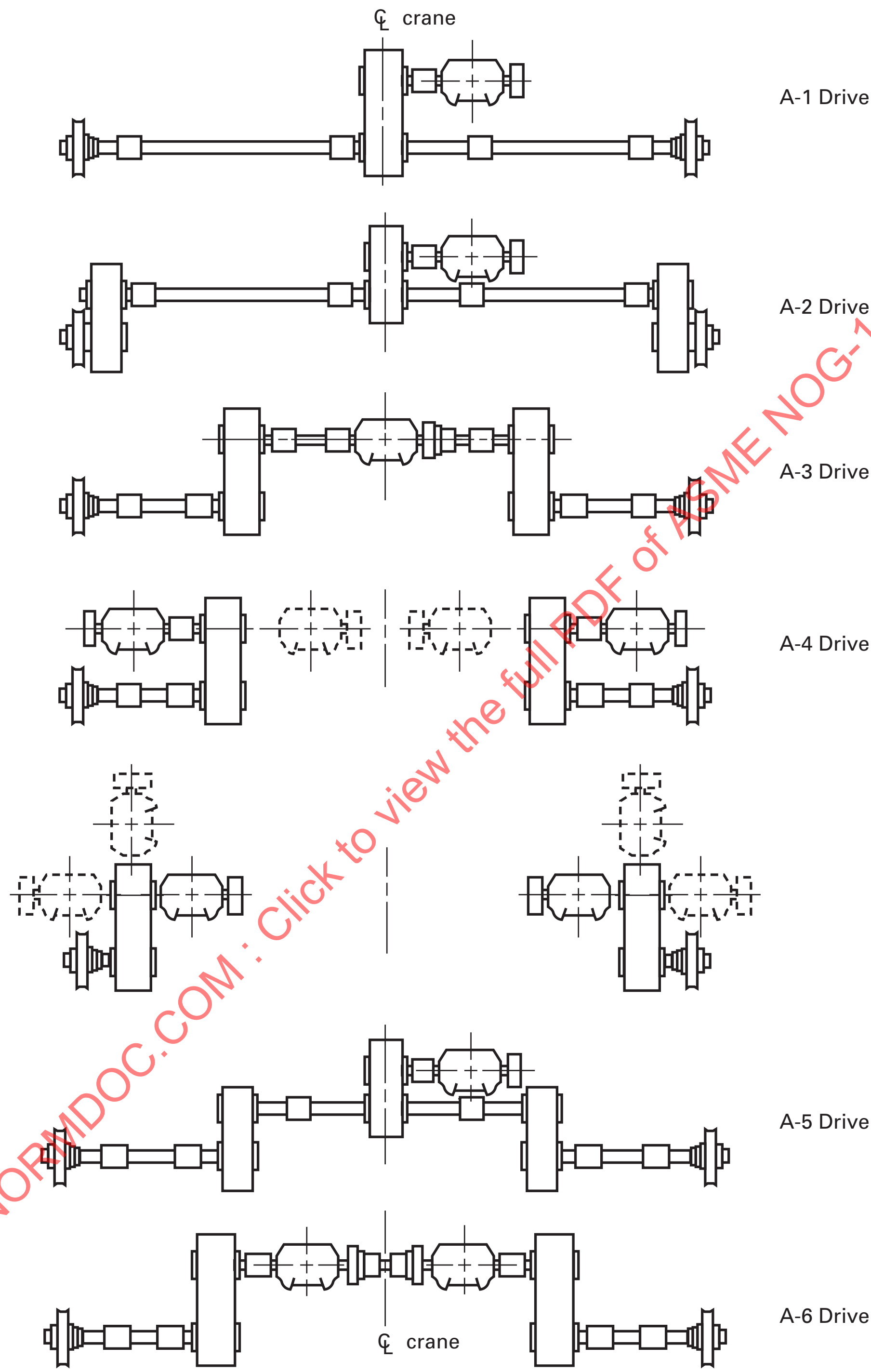
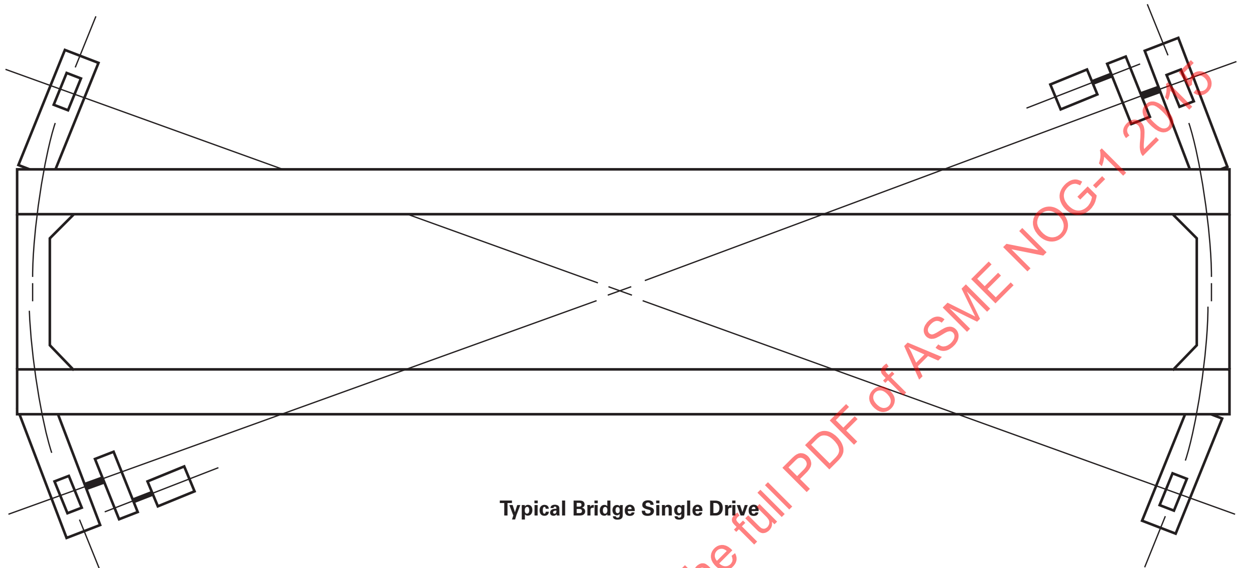
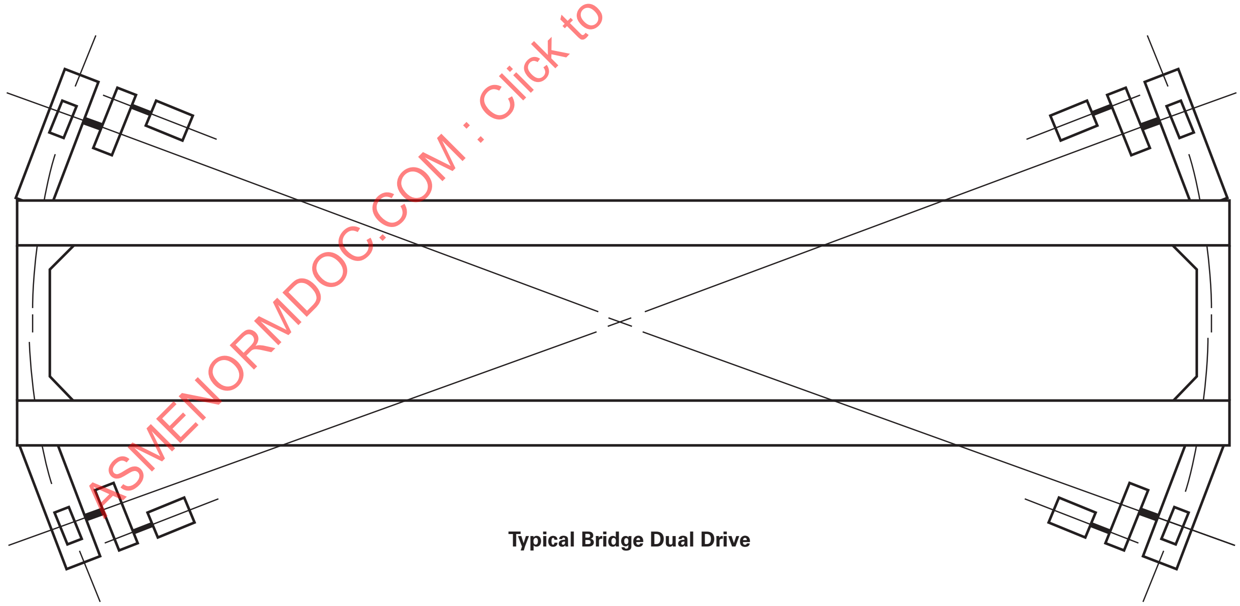


**Fig. 5440-2 Arrangement of Polar Cranes**



Typical Bridge Single Drive



Typical Bridge Dual Drive

by means of either suitable shafts with couplings or directly mounted to the wheel axle shaft extension. Another variation of this drive would separate the high-speed and final reductions by locating the motors near each end of the bridge without torque shafts. The motors will be connected to self-contained, high-speed gear boxes with pinions mounted on the output shafts of the high-speed gear boxes that will drive the truck wheels through gears pressed and keyed on their axles or by gears fastened to the truck wheels.

*(5) A-5 Drive.* The motor is located near the center of the bridge and is connected by means of a flexible coupling to a self-contained gear reduction unit located near the center of the bridge. This reduction unit shall be connected by sections of line shaft having solid or half-flexible couplings to self-contained gear reduction units located near each end of the bridge, and these, in turn, shall be connected to bridge wheel axles by means of floating shafts with half-flexible couplings [see (a)(7) below, Note].

*(6) A-6 Drive.* The motors are located near each end of the bridge and are connected with a torque shaft. On the drive end, the motor shall be connected to a self-contained gear reduction unit by means of flexible couplings. Gear reduction units are to be connected to bridge wheel axles by means of floating shafts with half-flexible couplings. High-speed shafts between motors shall be connected by half-flexible couplings. All other couplings shall be of the solid type.

*(7)* Typical bridge drive arrangements for polar cranes are shown in Fig. 5440-2. These drives use the A-4 drive arrangement with the axis of bridge wheel rotation passing through the center of the crane runway diameter.

NOTE: A-1, A-2, and A-5 drives can result in a torsionally very soft drive system if center gear ratios and/or bridge spans are of large magnitude. Natural frequency and amplitude of total torsional deflection of the drive system should be determined. Low frequencies and large total deflections are undesirable for crane operation.

*(b) Types II and III Cranes.* Arrangement of bridge drives is the same as for Type I cranes.

### 5441 Motors — Bridge

**5441.1 Type I Cranes.** Each bridge drive arrangement, as described in para. 5440 and shown in Figs. 5440-1 and 5440-2, shall use one or more motors for traversing the bridge. Motor(s) shall be selected in accordance with para. 6400.

**5441.2 Types II and III Cranes.** Bridge drive motors shall be in accordance with CMAA 70.

**5441.3 Ratings.** If 60-min series wound motors are used, then special consideration shall be given to the short time torque ratings of such motors.

### 5442 Bridge Travel Gearing

**5442.1 Type I Cranes.** Bridge travel gearing shall be designed in accordance with para. 5413, except for the areas delineated in this Section. The actual horsepower imposed on the gearing shall be considered as the rated motor horsepower, at its normal time rating, unless 60-min series wound motors are used (see para. 5441.3).

**5442.2 Types II and III Cranes.** Gearing for bridge travels shall be established in accordance with the provisions of CMAA 70.

### 5443 Bridge Brakes

**5443.1 Type I Cranes**

*(a) Service Brakes.* A bridge drive system shall be provided with a service braking means that may be satisfied by the parking brake, a separate control brake, or as part of the motor controls. Service brake requirements, brake sizes, and brake designs are specified under Section 6000.

*(b) Emergency and Parking Brakes.* Each primary bridge drive motor shall be provided with an emergency and a parking brake. Brake sizing and design are specified under Section 6000.

**5443.2 Types II and III Cranes.** Bridge brakes shall be in accordance with CMAA 70.

## 5450 General Mechanical Components

### 5451 Couplings (Types I, II, and III Cranes)

**5451.1 General** (15)

*(a)* Couplings connecting the motor(s) to the hoist and travel gear reducer(s) shall be the flexible type. Grease-lubricated couplings are preferred with gear types. Flexible motor couplings are not required for self-contained bridge and trolley gear reduction units with integral motors.

*(b)* Cross-shaft couplings, other than the flexible type, shall be steel as specified by the coupling manufacturer. The coupling (other than flexible) may be compression, sleeve, or flange type.

**5451.2 Selection**

*(a)* Coupling selection shall be based on the manufacturer's rating and applicable service factors for crane motions compared to the applied torque on the coupling, giving consideration to the following:

*(1)* motor output

*(2)* gear ratio

*(3)* efficiency of system

*(4)* wheel slippage with maximum operating wheel load (friction = $\mu$ = 0.2)

*(5)* dynamic effects

*(6)* brake torque

*(b)* In no case do all of the loading conditions occur simultaneously, and consideration should be given to

the applicable conditions, such as minimum wheel slippage or motor output torque.

### 5452 Wheels — Bridge and Trolley

**5452.1 General.** Unless other means of restricting lateral movement are provided, wheels shall be double flanged with treads accurately machined. Wheels may have either straight treads or tapered treads assembled with the large diameter toward the center of the span. Drive wheels shall be matched pairs within 0.001 in./in. of diameter, or a total of 0.010 in. on the diameter, whichever is smaller. When flangeless wheel and side roller assemblies are provided, they shall be of a type and design recommended by the crane manufacturer.

**5452.2 Material.** Wheels shall be rolled or forged from steel for Type I cranes. Types II and III cranes may have wheels cast of carbon or alloy steel. Wheel treads shall have a minimum surface hardness of 300 BHN.

**5452.3 Loading.** Wheels shall be designed to carry the maximum wheel load under normal conditions. The allowable maximum wheel load is determined by dividing the allowable wheel load in Table 5452.3-1 by the appropriate speed factor of Table 5452.3-2. The allowable wheel load shown in Table 5452.3-1 is that load produced with trolley handling the rated load in the position to produce the maximum load and shall be used for determining wheel sizes. Impact loading due to handling rated load is not included in the allowable wheel loads.

**5452.4 Clearances**

(a) *Bridge Clearances.* Wheel treads shall be a minimum of 3⁄4 in. wider than the rail head for nontapered wheels.

(b) *Trolley Clearances.* Wheel treads shall be a minimum of 3⁄8 in. wider than the rail head for nontapered wheels.

(c) *Tapered Wheel Clearances.* Tapered tread wheels may have a clearance over the rail head of 150% of the clearance provided for straight tread wheels, or as recommended by the crane manufacturer.

(d) *Special Conditions for Wheel Clearances.* Wheel tread clearances may be greater than those specified in Fig. 5452.4-1, if determined necessary to meet runway expansion requirements caused by excessive temperature and pressure. Refer to Section 1000. For guidance on wheel width and height, refer to Table 5452.4-1.

**5452.5 Axle Fits.** When rotating axles are used, wheels shall be mounted on the axle with a press fit alone or press fit and keys. All wheels shall have sufficient hub thickness to permit the use of keys.

**5452.6 Overhung Wheels.** Overhung wheels shall not be used.

### 5453 Axles — Bridge and Trolley

**5453.1 General — Type I Cranes.** Axles may be either of the fixed or rotating type.

(a) *Load Combinations, Allowable Stresses, and Service Factors.* The bridge and trolley axles shall be designed to resist the load combinations of Table 5453.1-1 with corresponding values of allowable stresses and service factors.

(b) *Computation — Analysis.* Analytical stress computations shall be performed according to procedures in para. 5470.

**5453.2 General — Type II Cranes.** Axles shall be designed according to CMAA 70.

**5453.3 General — Type III Cranes.** Axles shall be designed according to CMAA 70.

### 5454 Drive Shafts — Bridge and Trolley

**5454.1 General — Type I Cranes.** Drive shafting shall be designed for the rated load maximum wheel load in combination with the required torque. The magnitude of the torque shall be based on the drive output torque, skid torque, or braking torque, whichever is limiting.

(a) *Computation — Analysis.* Analytical stress computations shall be performed according to procedures in para. 5470.

(b) *Service Factors.* Service factors shall be applied according to para. 5320.

(c) *Torsional Deflection.* The torsional deflection of the cross-shafts and floating shafts shall not exceed the values, shown in Table 5454.1-1. The types of drives referred to in this table are defined in para. 5440. The percent motor torque is the portion of the full-load torque of the drive motor(s) at its normal time rating for the service involved, increased by any gear reductions between the motor and the shaft. If 60-min series wound motors are used, short time rating torques should be considered. The allowable angular deflection is expressed in degrees per foot (deg/ft).

**5454.2 General — Types II and III Cranes.** Drive shafting shall be designed according to CMAA 70.

### 5455 Bearings

**5455.1 Antifriction Bearings (Type I Cranes)**

(a) The type, size, and mounting of bearings shall be determined by criteria outlined in this Section. Computations confirming the adequacy of the bearing to meet the criteria shall be included as part of the crane analysis.

(b) Bearings with a calculable predicted life expectancy of a minimum of 5,000 hr shall be selected.

(1) Bearing life expectancy shall be determined from the bearing manufacturer's published data or certified extension of published data.

(2) Bearing life expectancy shall be expressed as the number of hours of operation in which 90% of the bearings are expected to operate without failure.

### Table 5452.3-1 Allowable Wheel Loads for Rim-Toughened Crane Wheels, *P*, lb, for Speed Factor = 1

| Wheel Diameter, in. | Rail Section | | | | | | |
|---|---|---|---|---|---|---|---|
| | ASCE 30# | ASCE 40# | ASCE 60# | BETH & USS 104–105# | BETH & USS 135# | BETH & USS 175# | BETH 171# |
| 8 | 11,840 | 13,930 | . . . | . . . | . . . | . . . | . . . |
| 9 | 13,220 | 15,670 | 21,940 | . . . | . . . | . . . | . . . |
| 10 | 14,800 | 17,410 | 24,370 | . . . | . . . | . . . | . . . |
| 12 | 17,770 | 20,890 | 29,250 | 31,340 | . . . | . . . | . . . |
| 15 | 22,210 | 26,110 | 36,560 | 39,170 | . . . | . . . | . . . |
| 18 | 26,650 | 31,340 | 43,880 | 47,010 | 56,410 | 78,350 | 87,760 |
| 21 | . . . | 36,560 | 51,190 | 54,850 | 65,820 | 91,410 | 102,380 |
| 24 | . . . | . . . | 58,500 | 62,680 | 75,220 | 104,470 | 117,010 |
| 27 | . . . | . . . | . . . | 70,520 | 84,620 | 117,530 | 131,640 |
| 30 | . . . | . . . | . . . | 78,350 | 94,020 | 130,590 | 146,260 |
| 36 | . . . | . . . | . . . | . . . | 112,830 | 156,710 | 175,520 |
| Effective rail width | 1.063 | 1.250 | 1.750 | 1.875 | 2.250 | 3.125 | 3.500 |

GENERAL NOTES:

(a) Allowable wheel load $P = KbD$, where

$b$ = effective width rail head

$D$ = diameter of wheel

(b)

$$K = 1{,}300\left(\frac{BHN}{260}\right)^{0.333} = 1{,}393$$

(c) BHN for rim-toughened wheels = 320

(d)

$$\text{Allowable maximum wheel load} = \frac{\text{allowable wheel load}}{\text{speed factor}}$$



### Table 5452.3-2 Speed Factor for Determining Allowable Maximum Wheel Load

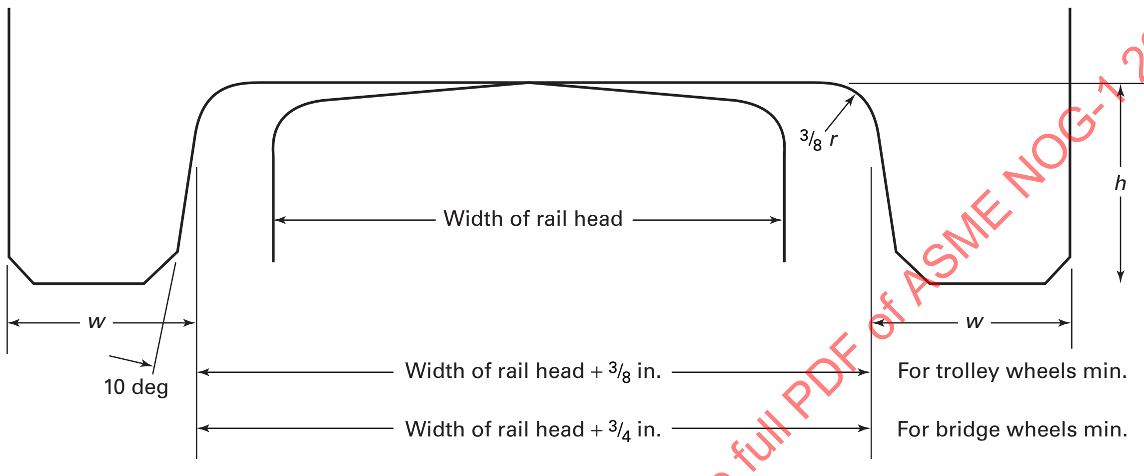
| Wheel Diameter, in. | Travel Speed, ft/min | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
| 8 | 0.958 | 1.013 | 1.049 | 1.086 | 1.122 | 1.158 | 1.195 | 1.267 | 1.340 | 1.413 | 1.485 | 1.558 | 1.631 |
| 9 | 0.944 | 1.001 | 1.033 | 1.066 | 1.098 | 1.130 | 1.163 | 1.227 | 1.292 | 1.356 | 1.421 | 1.485 | 1.550 |
| 10 | 0.932 | 0.984 | 1.020 | 1.049 | 1.079 | 1.108 | 1.137 | 1.195 | 1.253 | 1.312 | 1.369 | 1.427 | 1.485 |
| 12 | 0.915 | 0.958 | 1.001 | 1.025 | 1.049 | 1.074 | 1.098 | 1.146 | 1.195 | 1.243 | 1.292 | 1.340 | 1.389 |
| 15 | 0.898 | 0.932 | 0.966 | 1.001 | 1.020 | 1.040 | 1.059 | 1.098 | 1.137 | 1.175 | 1.214 | 1.253 | 1.292 |
| 18 | 0.887 | 0.915 | 0.944 | 0.973 | 1.001 | 1.017 | 1.033 | 1.066 | 1.098 | 1.130 | 1.163 | 1.195 | 1.227 |
| 21 | 0.879 | 0.903 | 0.927 | 0.952 | 0.977 | 1.001 | 1.015 | 1.043 | 1.070 | 1.098 | 1.126 | 1.153 | 1.181 |
| 24 | 0.873 | 0.894 | 0.915 | 0.937 | 0.958 | 0.980 | 1.001 | 1.025 | 1.049 | 1.074 | 1.098 | 1.122 | 1.146 |
| 27 | 0.869 | 0.887 | 0.906 | 0.925 | 0.944 | 0.963 | 0.982 | 1.011 | 1.033 | 1.055 | 1.076 | 1.098 | 1.119 |
| 30 | 0.865 | 0.882 | 0.898 | 0.915 | 0.932 | 0.949 | 0.967 | 1.001 | 1.020 | 1.040 | 1.059 | 1.079 | 1.098 |
| 36 | 0.860 | 0.873 | 0.887 | 0.901 | 0.915 | 0.929 | 0.944 | 0.973 | 1.001 | 1.017 | 1.033 | 1.049 | 1.060 |

GENERAL NOTE:

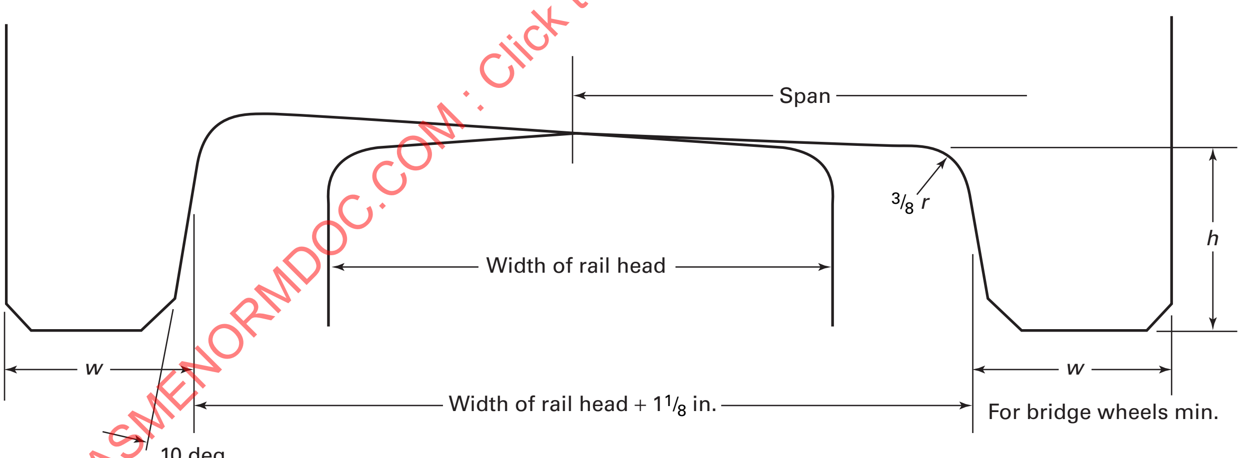
For rpm < 31.5: $\text{speed factor} = \left[1 + \left(\frac{\text{rpm} - 31.5}{360}\right)\right]^2$

For rpm ≥ 31.5: $\text{speed factor} = 1 + \left(\frac{\text{rpm} - 31.5}{328.5}\right)$

**Fig. 5452.4-1 Minimum Flange Widths and Heights**




Straight Tread Wheels




Tapered Tread Wheels

### Table 5452.4-1 Guide for Wheel Flange Width and Height

| Wheel Flange Width and Height | Wheel Diameter, in. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | 9 | 10 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 36 |
| Flange width, *w*, in. | 5/8 | 5/8 | 5/8 | 3/4 | 3/4 | 7/8 | 7/8 | 1 | 1 | 1 1/8 | 1 1/4 |
| Flange height, *h*, in. | 5/8 | 5/8 | 5/8 | 3/4 | 3/4 | 7/8 | 7/8 | 1 | 1 | 1 | 1 |

### Table 5453.1-1 Load Combinations — Bridge and Trolley Axles

| Crane Type | Load Combination [Note (2)] | Type of Loading [Note (1)] | | | | | | Allowable Stresses | Service Factor Minimum |
|---|---|---|---|---|---|---|---|---|---|
| | | Maximum Wheel Load | Side Thrust | Output Torque | Slipping Torque | Brake Torque | Seismic | | |
| Type I crane | 1 | X | X | X [Note (3)] | X [Note (3)] | . . . | . . . | 0.2 ULT | 1.0 |
| | 2 | X | X | . . . | X [Note (3)] | X [Note (3)] | . . . | 0.75 *Y* | 1.0 |
| | 3 | . . . | . . . | . . . | . . . | . . . | NA | . . . | . . . |
| Types II and III cranes | Per CMAA 70 | | | | | | | | |

NOTES:

(1) Type of loading:
Maximum wheel load: live load + dead load + impact load
Output torque: motor rating (nameplate) x gear ratio x efficiency x factor for drive arrangement
Slipping torque: maximum wheel load x 0.2 x diameter of wheel/2
Brake torque: applicable percentage of rated motor torque
Side thrust: force due to contact between wheel flange and side of rail head
Seismic: earthquake condition
Live load: rated load
Dead load: weight of crane (for bridge) or weight of trolley (for trolley)

(2) Load combinations:
Load combination 1 – normal operating
Load combination 2 – maximum overload-drive torque
Load combination 3 – seismic not applicable

(3) Minimum value of either output, sliding, or braking torque.

### Table 5454.1-1 Deflections

| Type of Drive | Maximum Allowable Deflection, deg/ft | Motor Torque, % |
|---|---|---|
| A-1 | 0.080 | 67 |
| A-2 | 0.080 | 50 |
| A-3 | 0.080 | 67 |
| A-4 | 0.070 | 100 |
| A-5 | 0.080 | 50 |
| A-6 | 0.070 | 100 |

*(3)* Analytical procedures may be based on L10 or B10, as defined by the American Bearing Manufacturers Association (ABMA).

*(4)* Infrequent loads, such as impact or seismic, need not be considered in bearing life computation.

*(5)* Bearing life computations shall be based on the full rated speed except as exempted herein. They may be based on less than full rated speed only if confirmed by the load spectrum, unless otherwise specified by the purchaser.

*(6)* Bearing life computations shall be based on the following minimum percentages of maximum load and load combinations.

*(-a)* Bridge drive bearings shall be computed using 75% of the maximum load, and shall be computed with no load acting against the wheel flange.

*(-b)* Trolley drive and wheel bearings shall be computed using 65% of the maximum load, and shall

be computed with no load acting against the wheel flange.

*(-c)* Hoist bearings shall be computed using 65% of the full rated load.

*(c)* Bearings shall be selected to withstand the maximum forces that may be imposed.

*(1)* Bearing capability shall be determined from the manufacturer's published data or certified extension of published data.

*(2)* The basic static capacity of the bearing shall not be exceeded by load combinations as outlined herein.

*(-a)* All bearings shall be sized to resist the maximum operating force that can be imposed by the driving motors.

*(-b)* Wheel bearings shall be designed to resist forces due to the maximum wheel load.

*(3)* Loads imposed by the safe shutdown earthquake (SSE) shall not exceed 90% of the bearings' minimum fracture limit.

*(d)* Mounting fits and internal clearances shall be as recommended by the bearing manufacturer.

*(e)* All bearings shall be provided with proper lubrication or means of lubrication.

*(f)* Bearing enclosures shall be designed as far as practical to exclude dirt and prevent leakage of oil or grease.

*(g)* Assemblies shall be analyzed to confirm that deflection under load does not exceed that which the bearing can accommodate.

*(h)* Special consideration shall be given to bearings that operate at speeds above or below the manufacturer's published data. Certified confirmation of the bearing's capacity beyond published rating must be obtained from the manufacturer.

*(i)* For bearings of load blocks that are to be immersed

*(1)* lubricants of these bearings shall be compatible with the chemistry of the liquid (refer to Section 1000 for special environmental conditions)

*(2)* provisions shall be made for relubricating the bearings once the block has been removed from the liquid

**5455.2 Antifriction Bearings (Types II and III Cranes)**

*(a)* Refer to CMAA 70.

*(b)* For bearings of load blocks that are to be immersed

*(1)* lubricants of these bearings shall be compatible with the chemistry of the liquid (refer to Section 1000 for special environmental conditions)

*(2)* provisions shall be made for relubricating the bearings once the block has been removed from the liquid

**5455.3 Sleeve Bearings (Type I Cranes)**

*(a)* Only bearings with published and/or certified properties shall be used.

*(b)* The PV (pressure velocity) rating of the bearing shall not be exceeded for any combination of operating loads.

*(c)* Forces induced by the SSE shall not exceed 90% of the allowable compressive strength of the bearing.

*(d)* All bearings shall be provided with proper lubrication or means of lubrication.

*(e)* Mounting fits and clearances shall be as recommended by the bearing manufacturer.

*(f)* Bearing enclosures shall be designed as far as practical to exclude dirt and prevent leakage of oil or grease.

**5455.4 Sleeve Bearings (Types II and III Cranes).** Refer to CMAA 70.

### 5456 Fasteners — Mechanical Components

**5456.1 Fastener Restraints**

*(a) Types I and II Cranes*

*(1)* Fasteners shall not loosen under normal operating loads and vibration.

*(2)* Cranes that travel over the reactor pool or fuel pool shall use fasteners that do not depend upon lock washers unless they are so located as to be caught upon removal by drip pans or crane structure. For these cranes, when other than high-strength bolts are used, preferred locking methods are thread-upsetting fasteners, plastic insert fasteners, tack welding, cementing, or lock wire. High-strength bolts are considered restrained when torqued in accordance with the AISC method.

*(b) Type III Cranes.* Fasteners shall be in accordance with CMAA 70.

**5456.2 Allowable Stresses**

*(a) Types I and II Cranes.* Maximum combined stresses induced in the fasteners by normal operating loads (but not including pretensioning loads) shall not exceed 20% of the ultimate strength of the fasteners. Limiting loads (such as seismic, stall torque, and load hang-up) shall induce combined stresses (not including pretensioning stresses) that do not exceed 90% of the yield strength of the fasteners.

*(b) Type III Cranes.* Maximum combined stresses induced in the fasteners by normal operating loads (not including pretensioning loads) shall not exceed 20% of the ultimate strength of the fasteners.

**5456.3 Mounting of Machinery**

*(a) Types I and II Cranes*

*(1)* Mounting surfaces for machinery (except for bridge) shall be machined for direct mounting or with allowance for shimming as dictated by the design.

*(2)* Single machinery elements such as motors and gear reducers shall not be mounted on multiple support structures that can deflect relative to each other unless the design specifically allows for this deformation.

*(3)* Machinery or machine parts whose alignment is important to its operation shall not depend on friction but shall use positive means such as dowel pins, shear bars, or fitted bolts to maintain alignment.

*(4)* Gear engagements shall be protected such that equipment deformation could not cause disengagement and drop the load.

*(5)* Machinery weights shall be increased by appropriate dynamic factors and analyzed by the static

method to determine fastener mounting loads. Allowable stresses shall be in accordance with para. 5456.2.

*(b) Type III Cranes*

*(1)* Mounting surfaces for machinery (except for bridge cross-shafting) shall be machined for direct mounting or with allowable for shimming as dictated by the design.

*(2)* Single machinery elements such as motors and gear reducers shall not be mounted on multiple support structures that can deflect relative to each other unless the design specifically allows for this deformation.

*(3)* Machinery or machine parts whose alignment is important to its operation shall not depend on friction but shall use positive means such as dowel pins, shear bars, or fitted bolts to maintain alignment.

*(4)* Gear engagements shall be protected such that equipment deformation could not cause disengagement and drop the load.

## 5457 Gear Cases, Enclosures, and Guards

### 5457.1 Gear Cases (Type I Cranes)

*(a)* All gears except final reduction gears shall be completely enclosed in gear cases. All gear cases shall be oil-tight and sealed with compound or gaskets.

*(b)* Unless otherwise approved by the owner, the hoist motion gear case base shall be split in one plane through the bearing center lines above the oil level except in microdrives and worm drives.

*(c)* Openings when provided shall be provided in the top section for the inspection of gearing at mesh lines. Covers for these inspection holes shall be sealed to prevent leakage.

*(d)* Splash oil lubrication of bearings may be used unless otherwise specified.

*(e)* Oil pumps shall be used if vertical gearing exceeds two reductions. The oil level on horizontally arranged gearing shall be high enough to immerse the bottom portion of at least two gears.

*(f)* Solid oil seals should be selected to allow replacement with split seals, if possible.

*(g)* Easily accessible drain plugs and breathers shall be provided.

*(h)* All hoist gear cases shall be mounted on machined surfaces.

*(i)* Gear cases shall be provided with lugs or other means of lifting.

*(j)* Means for checking oil level shall be provided.

**5457.2 Gear Cases (Types II and III Cranes).** Gear cases shall be in accordance with CMAA 70.

### 5457.3 Enclosures for Gears (Type I Cranes)

*(a)* All gears not enclosed in gear cases shall be provided with guarded enclosures. This is primarily for the final gear reduction at the hoist drum and travel motion drive wheels.

*(b)* All gear enclosures shall be designed to retain lubricant.

*(c)* Openings shall be provided in the top section for the inspection of the gearing at the mesh lines. Covers for these inspection holes shall be sealed to prevent leakage.

*(d)* Openings for shafts or other rotating parts such as drums shall be provided with means to retain the lubricant.

*(e)* Gear enclosures shall be provided with lugs or other means of lifting.

**5457.4 Enclosures for Gears (Types II and III Cranes).** Gear enclosures shall be in accordance with CMAA 70.

### 5457.5 Guards for Moving Parts (Types I, II, and III Cranes)

*(a)* Exposed moving parts such as gears, set screws, projecting keys, chains, chain sprockets, and reciprocating components, which may constitute a hazard, shall be guarded.

*(b)* Guards shall be securely fastened.

*(c)* Each guard shall be capable of supporting the weight of a 200-lb person without permanent deformation, unless the guard is located where it is impossible for a person to step on it.

### 5457.6 Guards for Hoisting Ropes (Types I, II, and III Cranes)

*(a)* If hoisting ropes run near enough to other parts to make fouling or chafing possible under normal operating conditions, guards shall be installed to prevent this condition.

*(b)* A guard shall be provided to prevent contact between bridge or runway conductors and hoisting ropes if they can come into contact under normal operating conditions.

## 5458 Bumpers and Stops

### 5458.1 Bridge Bumpers (Type I Cranes)

*(a)* Bumpers shall be sized to limit impact and critical load excursions to facility acceptable magnitudes.

*(b)* A crane shall be provided with bumpers. These bumpers shall have the following minimum characteristics:

*(1)* energy absorbing (or dissipating) capacity to stop the crane when traveling with power off in either direction at a speed of at least 40% rated load speed (refer to para. 5459 on limit switches for limiting speed upon bumper impact)

*(2)* capable of stopping the crane (not including load block and lifted load unless guided vertically) at a rate of deceleration not to exceed an average of 3 ft/sec$^2$ when traveling with power off in either direction at 20% of rated load speed

*(3)* mounted such that there is no direct shear on bolts upon impact

(c) Bumpers shall be designed and installed to minimize parts falling from the crane in case of breakage or loosening of bolted connections.

(d) When more than one crane is located and operated on the same runway, bumpers shall be provided on their adjacent ends to meet the requirements stated above.

(e) Bumpers are not required on polar cranes unless limited rotation is desired.

**5458.2 Bridge Bumpers (Types II and III Cranes).** Bridge bumpers shall be in accordance with CMAA 70.

**5458.3 Trolley Bumpers (Type I Cranes)**

(a) Bumpers shall be sized to limit impact and critical load excursions to facility acceptable magnitudes.

(b) A trolley shall be provided with bumpers. These bumpers shall have the following minimum characteristics:

(1) energy absorbing (or dissipating) capacity to stop the trolley when traveling with power off in either direction at a speed of at least 50% rated load speed (refer to para. 5459 on limit switches for limiting speed upon bumper impact)

(2) capable of stopping the trolley (not including load block and lifted load unless guided vertically) at a rate of deceleration not to exceed an average of 4.7 ft/sec$^2$ when traveling with power off in either direction at one-third of rated load speed

(3) mounted such that there is no direct shear on bolts upon impact

(c) Bumpers shall be designed and installed to minimize parts falling from the crane in case of breakage or loosening of bolted connections.

(d) When more than one trolley is located and operated on the same bridge, bumpers shall be provided on their adjacent ends to meet the requirements stated above.

**5458.4 Trolley Bumpers (Types II and III Cranes).** Trolley bumpers shall be in accordance with CMAA 70.

**5458.5 Trolley Stops (Type I Cranes)**

(a) Stops shall be provided at the limits of travel of the trolley.

(b) Stops shall be designed to withstand the forces applied to the bumpers as specified in para. 5458.

(c) If a stop engages the tread of the wheel, it shall not be of a height less than the radius of the wheel. Stops engaging other parts of the crane are recommended.

(d) Stops shall be mounted such that there is no direct shear on the bolts upon impact.

**5458.6 Trolley Stops (Types II and III Cranes).** Trolley stops shall be in accordance with CMAA 70.

### 5459 Limit Switches

**5459.1 Limit Switches (Type I Cranes)**

(a) Track type for bridge and trolley travel motion (see para. 6447 for application and function).

(b) Geared type for upper and lower travel hoist motion (see para. 6447 for application and function).

(c) Weight and paddle-operated type for upper travel hoist motion (see para. 6447 for application and function).

(d) A trolley track-type limit switch or other device shall be provided and positioned to ensure that, under operating conditions, the trolley speed cannot exceed 50% of rated load speed on engaging the trolley stops and bumpers.

(e) A bridge track-type limit switch or other device shall be provided and positioned to ensure that, under operating conditions, the bridge speed cannot exceed 40% of rated load speed on engaging the bridge stops and bumpers.

**5459.2 Limit Switches (Types II and III Cranes).** Limit switches shall be in accordance with CMAA 70.

**5459.3 Clearances.** For determining clearances between the trolley structure and the load block in its high position, allowance shall be made for lift, trip, and drift as shown in Figs. 5459.3-1 and 5459.3-2.

## 5460 Lubrication

### 5461 Type I Cranes

(a) Sheave bearings shall be individually lubricated and accessible for lubrication from the trolley deck for the head block assembly and the operating floor for the load block assembly. Load blocks that are immersed in water shall have special provisions to prevent loss of lubricant to the water (refer to para. 1100).

(b) Hoisting ropes, except for stainless steel ropes (consult manufacturer), shall be lubricated. When ropes are immersed in water, the lubricant type shall be selected to reduce the loss of lubricant to the water.

(c) Lubricants for gears, bearings, and wire ropes shall resist effects of gamma or neutron radiation when such effects are present, or facilities shall be provided for changing of the lubricants.

(d) If lubricants cannot be conveniently changed, but are subjected to neutron or gamma radiation, then lubricants shall be NLGI Grade 0 oil containing molybdenum disulfate or NLGI Grade 1½ grease with sodium aluminate thickener. They shall be oxidation and rust inhibited with the exception of wire rope lubricants.

(e) Provisions shall be made to prevent lubricants falling from the crane.

(f) For all above paragraphs, refer to Section 1000.

**5462 Types II and III Cranes.** Lubrication shall be in accordance with CMAA 70, unless the crane is subjected to radiation. If Types II and III cranes are subjected to radiation, then the provisions of para. 5461 apply.

## 5470 Analytical Procedures

It is the purpose of para. 5470 to apply common language for the terms, symbols, data, and formulas that

**Fig. 5459.3-1 Power or Control Circuit Limit Switch With Geared Upper Limit Switch**

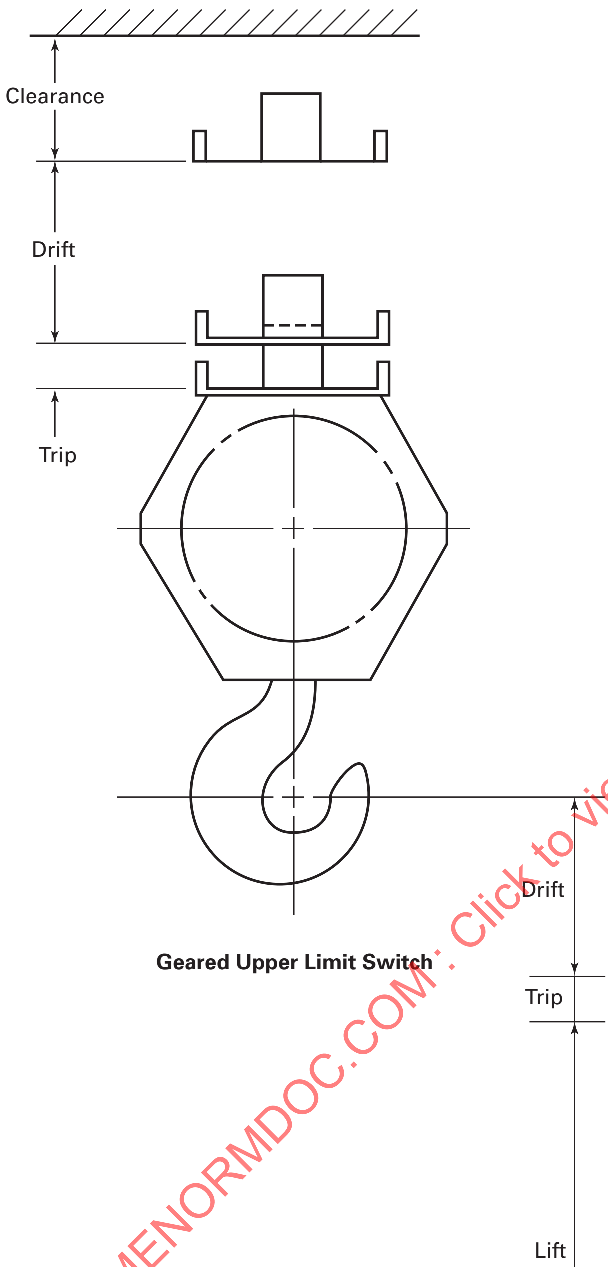
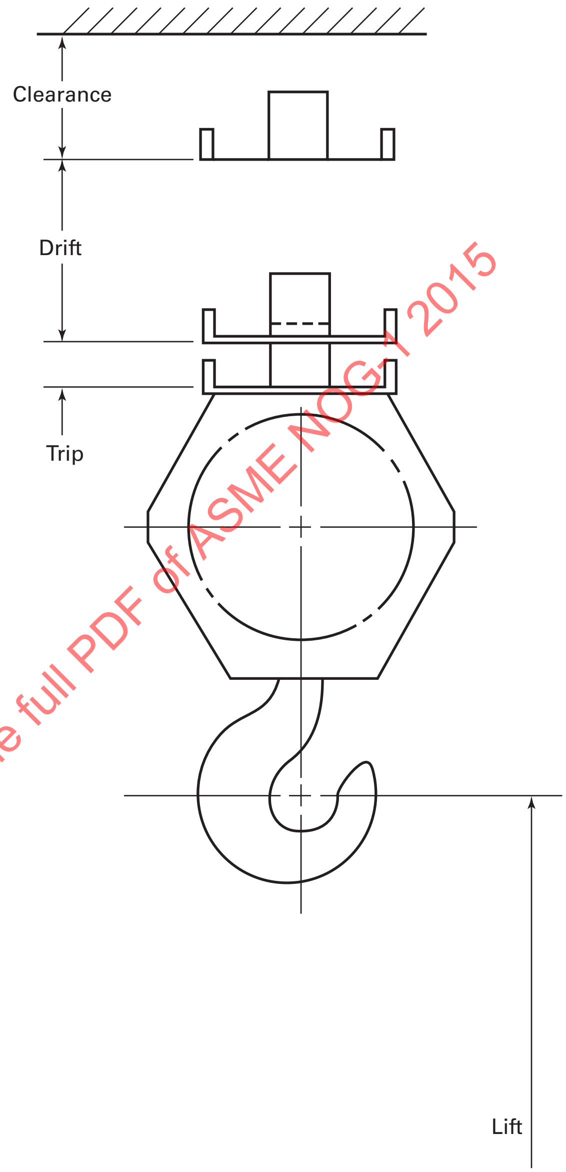



**Fig. 5459.3-2 Power or Control Circuit Limit Switch**






apply most frequently in the process of mechanical crane engineering. The effects of service and stress concentrations are treated separately from the allowable stresses to conform with actual service conditions and actual design geometry.

*(a)* The basic stress formulas have been listed to achieve uniformity in recording and combining of design stresses throughout the industry. Where applicable, formulas and symbols shall be used as defined in this Standard. All other formulas and symbols used in design calculations shall conform as far as possible to the method outlined and shown. The given data apply to low and medium carbon steel (usually used as hot rolled and normalized) and to heat treated alloy steel (usually used as quenched and tempered).

*(b)* Material strength properties have been treated on the basis of ultimate strength because it has a good relationship to the fatigue strength. No differentiation has been made between various materials because of the wide scatter of fatigue strength for each individual heat or each finished component. Heat treated alloy bar has, on the average, higher fatigue strength than medium carbon steel of the same ultimate tensile strength.

(c) Progressive fatigue failure represents the most common mode of failure in crane machinery. The design criteria of this Standard are, therefore, directed mainly to the prevention of accumulative damage to the material of mechanical crane components.

**5471 Stress Concentration Factors (Type I Cranes)**

(a) Stress concentration factors, $K_{NB}$, $K_{NS}$, and $K_{NT}$, for shafting in bending, shear, and torsion may be obtained from *Stress Concentration Factors* by R. E. Peterson.[1] These factors shall give consideration to the effects on the fatigue strength of fillet radii, as well as keyways, combined with heavy press fits.

Stress concentration factors for all other forms of notches (e.g., lubrication holes, threads, grooves) as well as other modes of stressing must also be considered and may be obtained from *Stress Concentration Factors*.[1]

(b) A combination of stress concentration factors must take place when two or more stress concentrations superimpose in one location — for example, keyway and/or press fit extending in the critical region of a shaft fillet. The proper stress concentration factors, $K_{NB}$ or $K_{NN}$, must be applied in calculating $\sigma_X$ or $\sigma_Y$ stresses, depending on whether $\sigma_X$ or $\sigma_Y$ are basically bending or tension–compression stresses. Stress concentration factors must be entered into calculation even if equal to 1.0.

**5472 Nomenclature.** See para. 5168.

**5473 Working Stresses.** The maximum working stresses in Class I crane machinery components shall not exceed the maximum allowable stresses, $\sigma_{BA}$, $\sigma_{NA}$, $\sigma_{XA}$, $\sigma_{YA}$, $\tau_A$, or $\tau_{TA}$, unless otherwise specified by the purchaser. The working stresses ($\sigma_B$, $\sigma_N$, $\sigma_{EBN}$, $\sigma_{EB}$, $\sigma_{EN}$, $\sigma_X$, $\sigma_Y$, $\sigma_{EXY}$, $\sigma_{EXYT}$, $\tau_X$, $\tau_T$, $\tau_{ET}$, $\tau_{XY}$, and $\tau_{EXYT}$) are uniaxial, biaxial, shear, combined, or equivalent stresses, which are induced in a mechanical component by the working (operational) loads. The maximum working loads shall include dead loads, maximum live loads, and acceleration and deceleration forces that result from normal operation of the crane. The maximum calculated working stresses shall include both service and stress concentration factors.

**5474 Allowable Stresses.** The allowable stresses, $\sigma_{BA}$, $\sigma_{NA}$, $\tau_A$, and $\tau_{TA}$, which shall be obtained from Figs. 5474-1, 5474-2, and 5474-3, vary with the minimum ultimate tensile strength, $\sigma_{UT}$, of the material in use, as well as with the fluctuation ratios, $R_B$, $R_N$, $R_S$, and $R_T$, of the working stresses. $\sigma_{XA}$ and $\sigma_{YA}$ shall be selected from Fig. 5474-1 or Fig. 5474-2, depending upon whether $\sigma_X$ or $\sigma_Y$ are basically bending or tension–compression stresses. $\tau_{TA}$ shall be selected directly from Fig. 5474-3.

**5475 Service Factors.** Service factors, $K_{SB}$, $K_{SN}$, $K_{SS}$, and $K_{ST}$, are to be based on para. 5320. Not all components within a crane drive system are necessarily subjected to the same service. Service factors shall give consideration to the following:

(a) risk and consequences of potential failure

(b) indeterminate load reactions (e.g., trolley with rigid frame supported on four track wheels)

(c) unpredictability of operation conditions (e.g., unexpected accidents within the building)

(d) dynamic effects (e.g., impacts in hoist mechanisms and seismic effects)

**5476 Basic Stress Equations**

(a) Where applicable, eqs. (17) through (31) must be used in determining basic stresses in crane machinery components. For determining size of machinery components, maximum working (operational) moments and shear loads, as well as critical section moduli, must be entered into these formulas.

(b) Sign convention must be observed when entering $\sigma_X$ and $\sigma_Y$ in eqs. (29) through (31). (Tension is positive; compression is negative.)

(c) Only stresses that occur simultaneously at the location where stress is being calculated should be combined.

(d) In eqs. (23) through (31), anisotropy and stress fluctuation have been given consideration in a simplified manner for easier use in the design engineering process.

(e) For sample calculation, refer to Nonmandatory Appendix B, para. B-5476.

(f) The following are the basic stress equations:

$$\sigma_B = \left(\frac{M_B}{S_B}\right)(K_{SB})(K_{NB}) \le \sigma_{BA},\ \text{ksi} \tag{17}$$

$$\sigma_N = \left(\frac{P}{A}\right)(K_{SN})(K_{NN}) \le \sigma_{NA},\ \text{ksi} \tag{18}$$

$$\sigma_{EBN} = \sigma_B + \left[\left(\frac{\sigma_{BA}}{\sigma_{NA}}\right)(\sigma_N)\right] \le \sigma_{BA},\ \text{ksi} \tag{19}$$

$$\tau_S = \left(\frac{Q}{I}\right)\left(\frac{P}{t}\right)(K_{SS})(K_{NS}) \le \tau_{NA},\ \text{ksi} \tag{20}$$

$$\tau_S = \left(\frac{1.33P}{A}\right)(K_{SS})(K_{NS}) \le \tau_A,\ \text{ksi} \tag{21}$$ [2]

$$\tau_T = \left(\frac{M_T}{S_T}\right)(K_{ST})(K_{NT}) \le \tau_{TA},\ \text{ksi} \tag{22}$$

$$\tau_{ET} = \tau_T + \left(\frac{\tau_{TA}}{\tau_A}\right)(\tau_{XY}),\ \text{ksi} \tag{23}$$

$$\tau_{EXYT} = \tau_T + \left[\left(\frac{\tau_{TA}}{\tau_{XYA}}\right)(\tau_{XY})\right] \le \tau_{TA},\ \text{ksi} \tag{24}$$

[1] Peterson, R. E., *Stress Concentration Factors*, John Wiley & Sons, New York, NY, 1974.

[2] Timoshenko, S., *Strength of Materials*, Second Edition, Part 2, D. Van Nostrand Co., New York, NY, 1941, p. 65.

**Fig. 5474-1 Allowable Bending Stress**

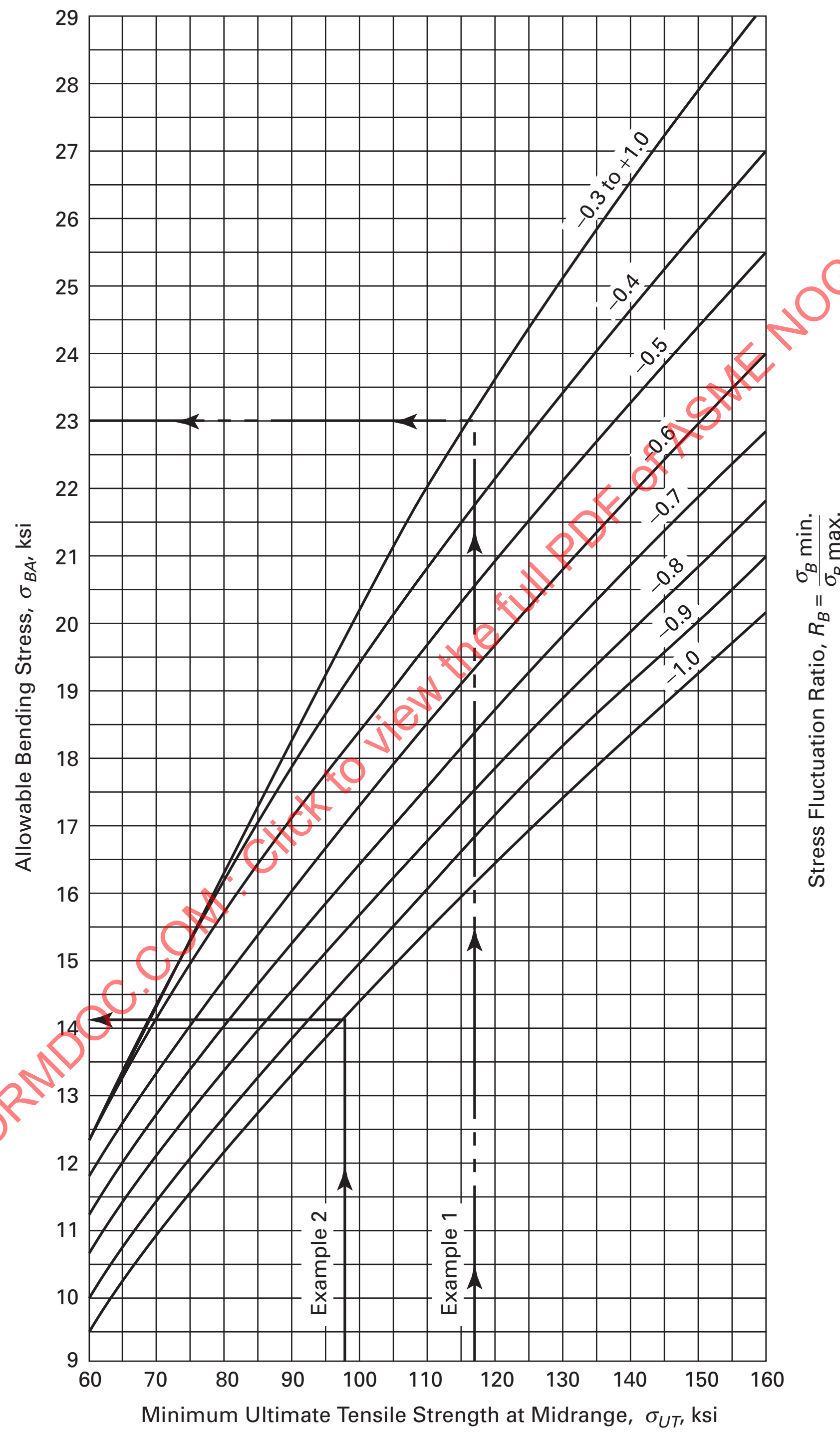


**Fig. 5474-2 Allowable Tension or Compression Stress**

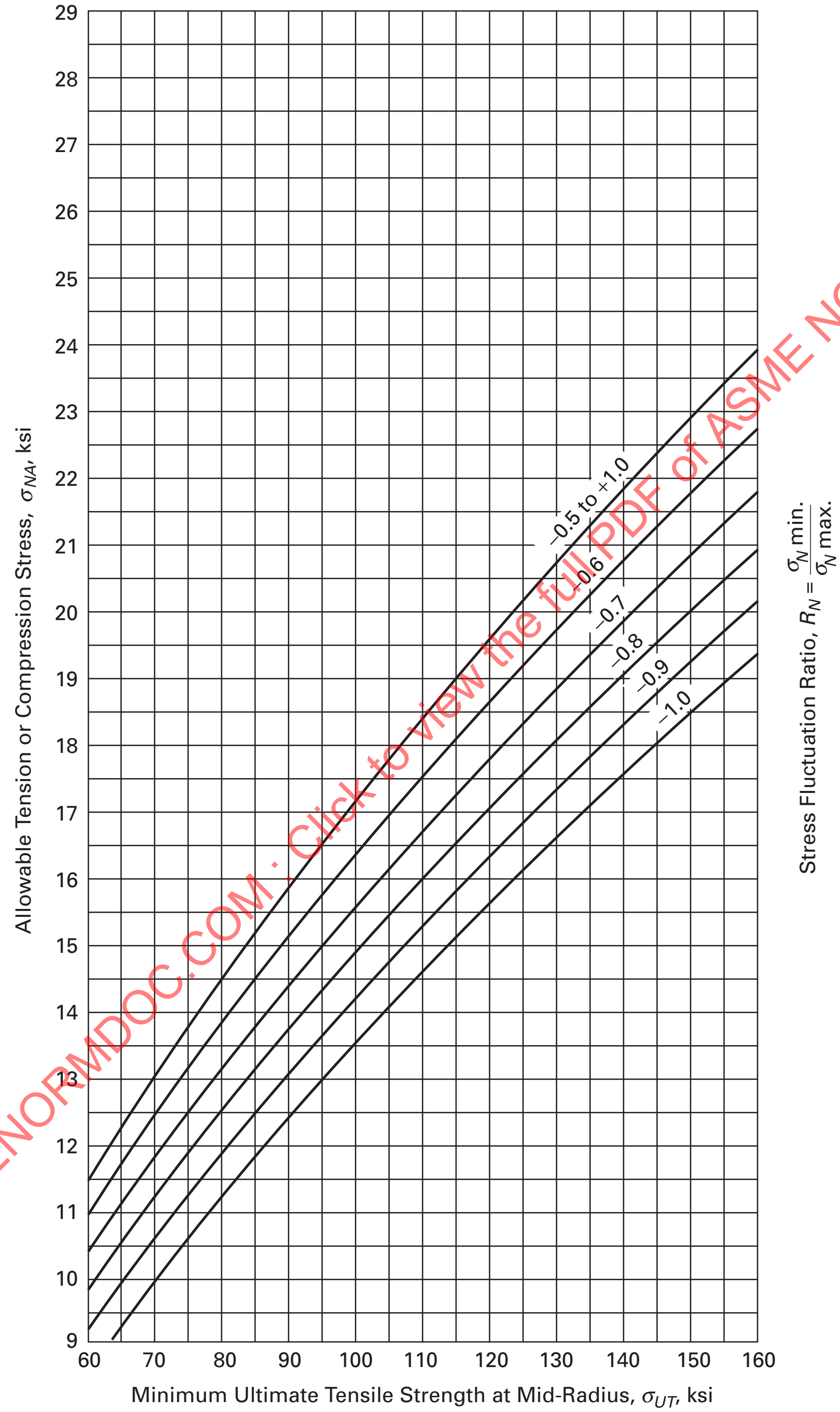


**Fig. 5474-3 Allowable Shear Stress**

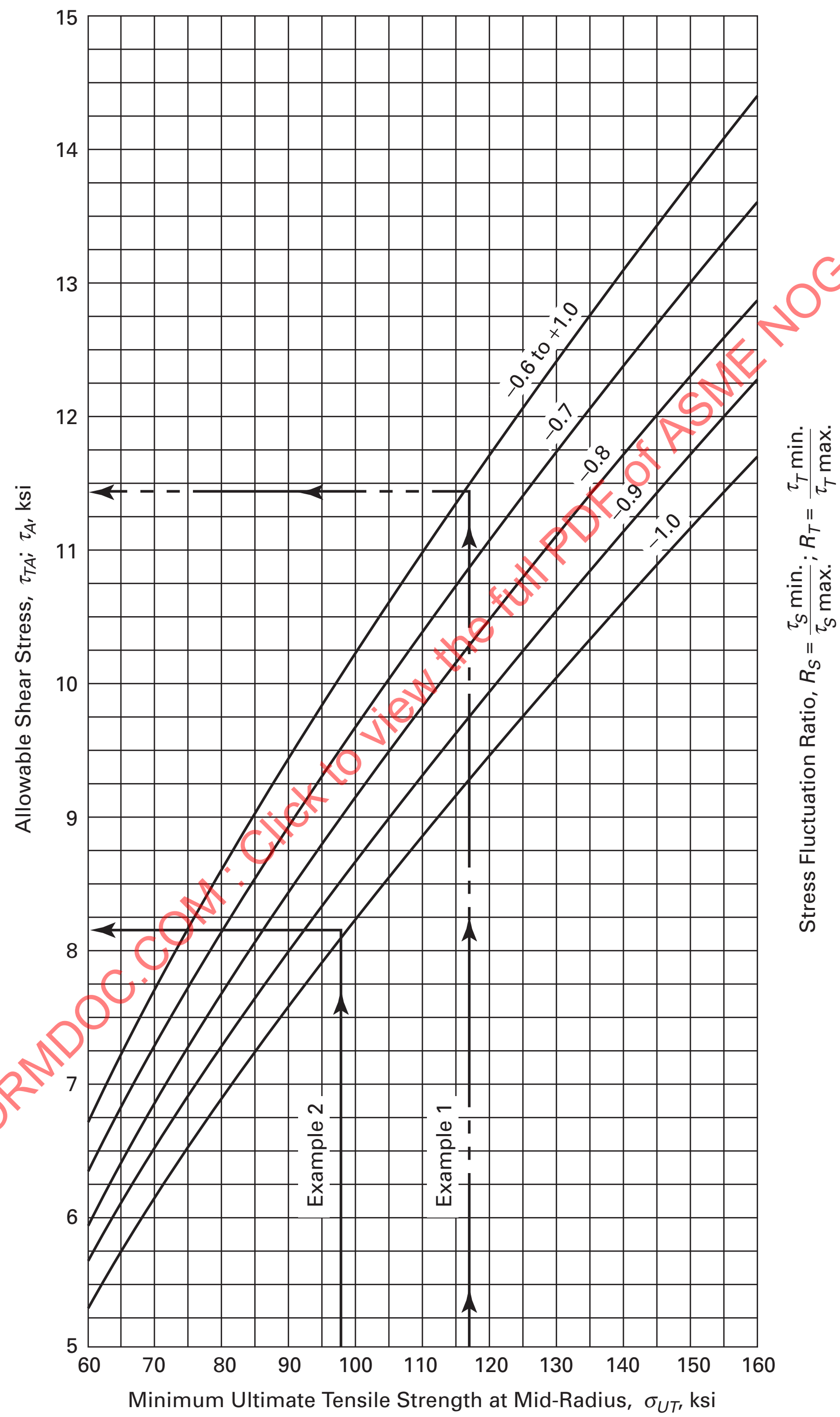


**Fig. 5477-1 Typical Hook Cross-Section**

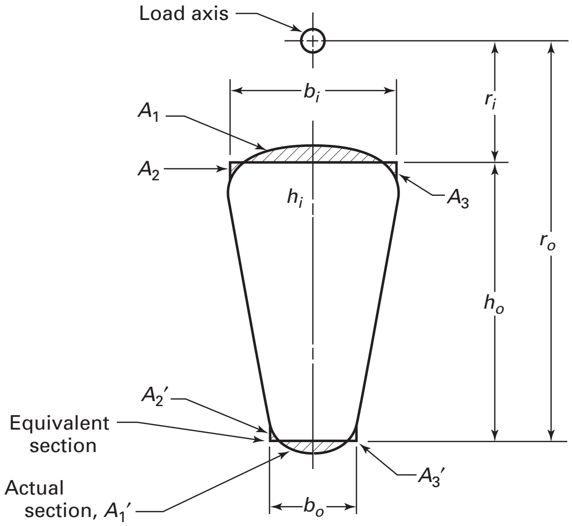
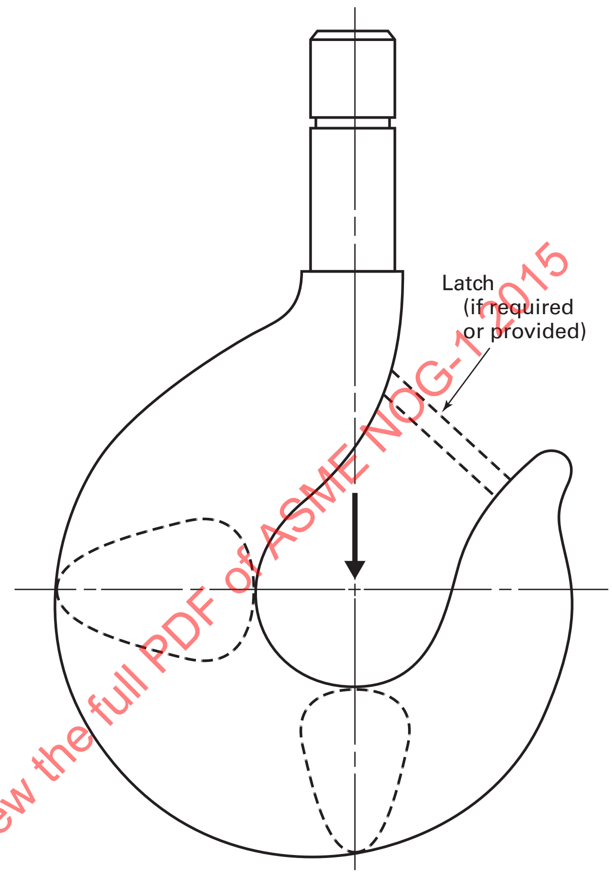



**Fig. 5477-2 Fish Hook Configuration**




$$\sigma_{EB} = \left\{ \sigma_B^2 + \left[ \left( \frac{\sigma_{BA}}{\tau_{TA}} \right)^2 (\tau_{ET}^2) \right] \right\}^{1/2} \quad (25)$$

$$\sigma_{EB} = \sigma_B K_{EB} \leq \tau_{BA}, \text{ ksi} \quad (26)$$

$$\sigma_{EN} = \left\{ \sigma_N^2 + \left[ \left( \frac{\sigma_{NA}}{\tau_{TA}} \right)^2 (\tau_{ET}^2) \right] \right\}^{1/2} \quad (27)$$

$$\sigma_{EN} = \sigma_N K_{EN} \leq \sigma_{NA}, \text{ ksi} \quad (28)$$

$$\sigma_{EXY} = \left\{ \sigma_x^2 + \left[ (\sigma_y^2) \left( \frac{\sigma_{XA}}{\sigma_{YA}} \right)^2 \right] - (\sigma_X) \left( \frac{\sigma_{XA}}{\sigma_{YA}} \right) (\sigma_y) \right] \right\}^{1/2} \leq XA, \text{ ksi} \quad (29)$$

$$\sigma_{EXYT} = (\sigma_X)(K_{EXY}) \leq \sigma_{XA}, \text{ ksi} \quad (30)$$

$$\sigma_{EXYT} = \left\{ \sigma_x^2 + \left[ (\sigma_y^2) \left( \frac{\sigma_{XA}}{\sigma_{YA}} \right)^2 \right] - \left[ (\sigma_X) \left( \frac{\sigma_{XA}}{\sigma_{YA}} \right) (\sigma_Y) \right] + \left[ \left( \frac{\sigma_{XA}}{\tau_{TA}} \right)^2 (\tau_{EXYT})^2 \right] \right\}^{1/2} \quad (31)$$

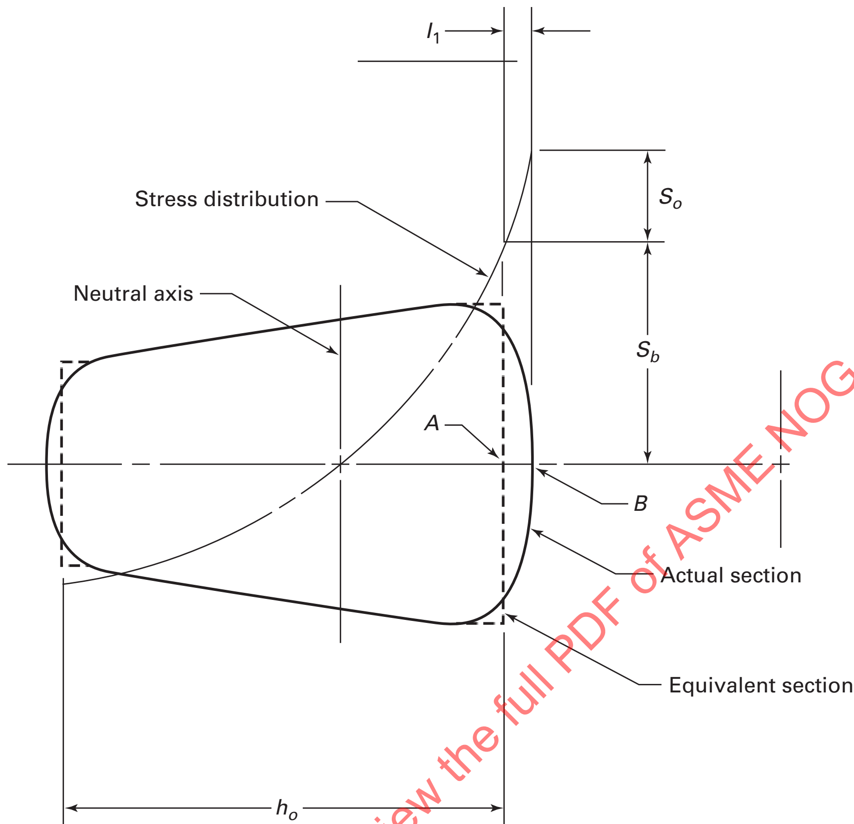
### 5477 Analytical Method for Hook of Approximate Trapezoidal Shape (Types I, II, and III Cranes)

*(a) Method of Analysis.* The analytical method given in this section is intended to apply to hooks with cross-sections having a shape as shown by the full line of Fig. 5477-1, which does not deviate significantly from a trapezoidal form. This includes a large number of practical crane-hook sections, such as shown in Fig. 5477-2. This method, while approximate, is much faster than the numerical integration method, and, in the cases to which it has been applied, it has given close agreement with the latter method.

Essentially, the analytical method is based on the assumption of an equivalent trapezoidal section having an area equal to that of the actual section. The stress computed in this way is then corrected for the stress increase in the neutral section resulting from the fact that the fibers nearest the center of curvature are farther from the neutral axis than in the case of the equivalent trapezoidal section. It is assumed that the resultant load on the hook passes through the center of curvature of the curved part and that the critical section is at 90 deg to the resultant load.

In Fig. 5477-1, the full lines represent the actual hook section, and the dashed lines the equivalent trapezoidal section. The equivalent section is so chosen that the shaded area $A_1$ is equal to the areas $A_2 + A_3$. Likewise, $A'_1 = A'_2 + A'_3$. In Fig. 5477-3, the distribution of stress over the section due to bending alone is indicated. It should be noted that the stress $S_b$ calculated from eq. (32) yields the bending stress at point $A$ at the inside of the equivalent trapezoid. Because of its greater distance from the neutral axis, the bending stress at point $B$ in the actual hook will be appreciably larger than that at

**Fig. 5477-3 Equivalent Section**






point $A$ by an amount $S_c$, as shown. If $l$ is the distance between the points $B$ and $A$, then the stress augment $S_o$ will be given approximately by

$$S_o = (l_1)\left(\frac{ds}{dy}\right)_o \tag{32}$$

where $(ds/dy)_o$ is the value (at point $A$, Fig. 5477-3) of the derivative of the stress $S$ with respect to distance $y$ from the neutral axis. From the equations of curved-bar theory, the derivative $(ds/dy)$ may be obtained, and by substitution in eq. (32) using the previous notations, the stress augment $S_o$ becomes

$$S_o = \frac{S_b K_2 l_1}{(r_i)\left(K_2 - \frac{1}{\beta - 1}\right)} \tag{33}$$

where $K_2$ is given by eq. (41).

The stress due to direct tension is

$$S_1 = P/A \tag{34}$$

where $A$ is the area of the cross-section

$$A = \frac{h_o\,(b_o + b_i)}{2} \tag{35}$$

where $h_o$ is the depth of the equivalent trapezoid (Fig. 5477-1).

The maximum stress, $S_{max}$, in the hook at the critical section will be the sum of the bending stress, $S_b$ [eq. (39)]; the stress augment, $S_o$ [eq. (33)]; and the direct tension stress, $S_1$ [eq. (34)]. This gives

$$S_{max} = S_b + S_o + S_1 \tag{36}$$

For Fig. 5477-1, let

$b_i$, $b_o$ = inside and outside widths of equivalent trapezoid, respectively
$r_i$, $r_o$ = inside and outside radii of equivalent trapezoid, respectively

$$\alpha = b_o/b_i \tag{37}$$

$$\beta = r_o/r_i \tag{38}$$

With these notations, the formulas for bending stress, $S_b$, at point $A$, Fig. 5477-3, at the inside of the trapezoidal section as derived from curved-bar theory becomes

$$S_b = \frac{2\,PK_1\left(K_2 - \frac{1}{\beta - 1}\right)}{b_i r_i\,(1 + \alpha)\,(K_1 - K_2)} \tag{39}$$

**Fig. 5477-4 Sister Hook Without a Pinhole**

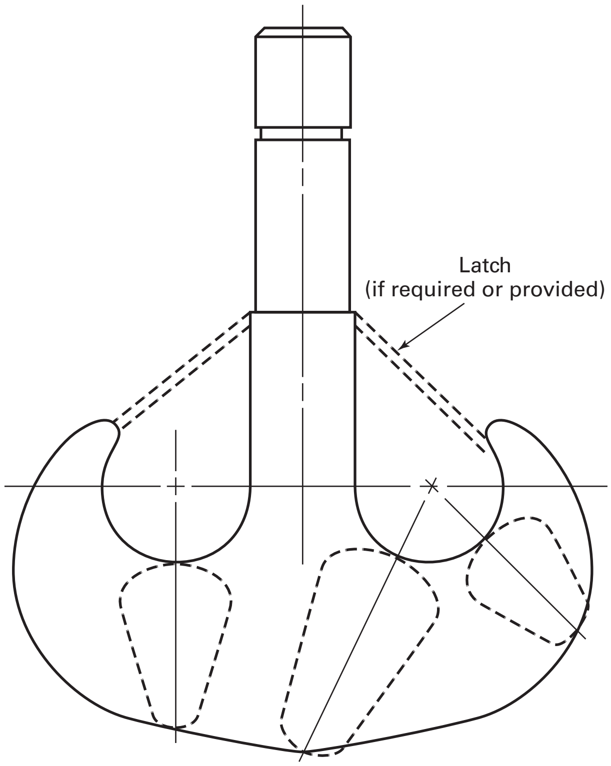
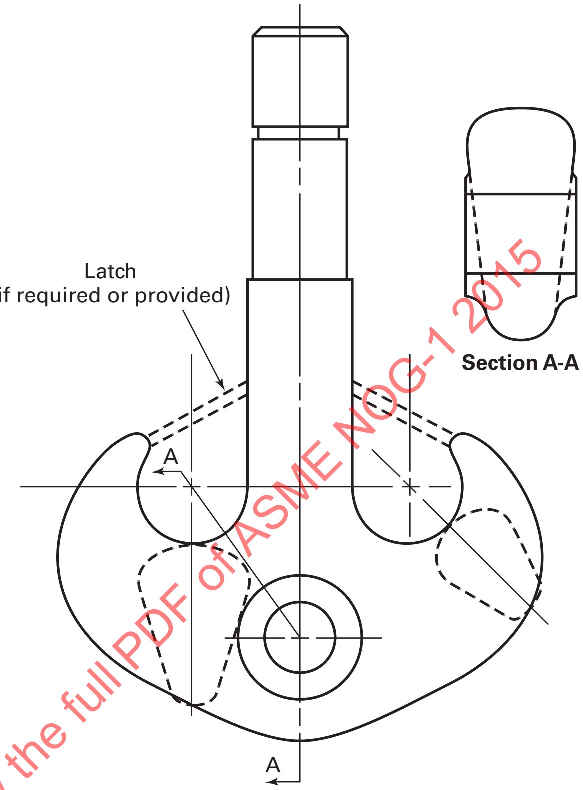



**Fig. 5477-5 Sister Hook With a Pinhole**






where

$$K_1 = \frac{1}{\beta - 1} + \frac{2\alpha + 1}{3(\alpha + 1)} \tag{40}$$

$$K_2 = \frac{\frac{1}{2}(1 + \alpha)}{\left[\frac{(\beta - \alpha)}{(\beta - 1)} \ln \beta\right] - (1 - \alpha)} \tag{41}$$

In general, the factors $K_1$ and $K_2$ should be calculated to at least four significant figures. For a sample calculation, see Nonmandatory Appendix B, para. B-5477.

*(b)* The method of analysis and design of a sister (duplex) hook shall be made using the straight beam configuration for the hook. Design of the sister (duplex) hook shall include due consideration for the sling angles (rigging) to be used during crane operation. Unless otherwise specified, hook design shall include provisions for a maximum sling angle of 30 deg from vertical (60 deg included sling angle). For sister (duplex) hooks provided with pinholes, the design shall include checks of the hook pinhole to ensure additional stress concentrations and shear tear out are addressed.

*(1)* Figure 5477-4 shows the general outline and a shade of a sister hook without a pinhole.

*(2)* Figure 5477-5 shows the general outline and shape of a sister hook with a pinhole.

*(c) References for Para. 5477*

*(1) Strength of Materials*, S. Timoshenko, Second Edition, Part 2, D. Van Nostrand Co., New York, NY, 1941, p. 65

*(2) Stresses in Curved Bars*, H. C. Perkins, Transactions of ASME, Vol. 53, 1931, p. 201

*(3) Mathematical Methods in Engineering*, Thomas von Karman and M. A. Biot, McGraw-Hill Book Co., 1940, p. 5

*(4) Stress Concentration Factors*, R. E. Peterson, John Wiley & Sons, New York, NY, 1974

## 5480 Seismic Analysis

### 5481 Type I Cranes

*(a)* Analysis confirming that the critical load will not be dropped as a result of the forces generated by seismic events shall be performed (see Section 4000).

*(1)* The analysis may be static if it includes loads equivalent to those that would be imposed by the seismic event specified.

*(2)* Loads due to vertical and horizontal motions shall act together and shall be combined in accordance with para. 4100.

*(3)* All elements which support the critical load shall be analyzed as follows and should not consider material fatiguing, stress concentration factors, and infinite life criteria.

*(-a)* The stress level at all critical points shall be determined.

*(-b)* The gross cross-section shall be used in determining the stress level.

*(-c)* The maximum stress level shall not exceed 90% of the yield strength of the material.

*(4)* All computations are to be based on the bulk cross-section of the material without consideration to any fatiguing effects of stress risers, or to the endurance limits of the material. The seismic forces according to the rules in para. 5300 are to be algebraically added to the forces and torques under normal operation.

*(b)* Analysis shall be performed to confirm that those components that would damage safety related equipment if dropped will remain in place during the seismic event.

*(c)* Components whose major resonant frequency is greater than 33 Hz may be analyzed as a lumped mass.

*(1)* Analysis shall consist of the determination of the stress level of the mounts when applying maximum dynamic forces to the center of gravity of the item.

*(2)* Loads shall be combined as in (a)(2) above.

*(d)* Components whose major resonant frequency is less than 33 Hz shall be analyzed dynamically.

#### 5482 Type II Cranes

*(a)* Analysis shall be performed to confirm that those components that would damage safety related equipment if dropped will remain in place during the seismic event.

*(b)* Such components shall be delineated by the bidding documents.

*(c)* Analysis shall be as listed in para. 5481.

**5483 Type III Cranes.** Seismic analysis is not required unless specified by the purchaser.

## 5500 MISCELLANEOUS

### 5510 Pendant Hoist and Travel Drives (Types I, II, and III Cranes)

**5511 Crane Pendant Mounting.** The crane purchaser shall prescribe whether pendant control stations, if furnished, are to be mounted from the trolley frame, fixed positions on the bridge, or a messenger trace on the bridge. The purchaser shall also prescribe whether the crane is to be pendant controlled from several elevations in the building. Whenever possible, the pendant should be suspended in a manner that minimizes undue strains on the electrical conductor cable. A chain or wire rope strain relief should be provided, unless the pendant is suspended directly from a motorized cable reel.

#### 5512 Messenger Track System

*(a)* The track itself should consist of a commercially available profile section, such as a rolled l-beam or an extrusion. A guide wire arrangement commonly known as a Tag-Line System shall be unacceptable for Type I cranes.

*(b)* Messenger trolleys shall be compatible with the track and shall be of sufficient load carrying capacity to suspend the combined weights of the pendant, cables, and accessories, as well as the pull that could be developed while maneuvering the control station. Messenger trolley rollers shall be mounted on sealed antifriction bearings and shall be provided with lubrication fittings unless bearings are lubricated for life. Individual messenger trolleys should be interconnected by strain relief chains or cables to reduce strains on the electrical control cables when traversing.

**5513 Motorized Traversing.** The crane purchaser shall prescribe whether pendant traversing is required. If furnished, the traversing tractor shall be controlled from the pendant station. If cable reels are suspended from a messenger track, consideration should be given to a motorized traversing system. Consideration should also be given to ensure that the pendant station is accessible to the operator after it has been lifted or lowered by a reel.

**5514 Vertical Travel of Control Pendant.** In cases where pendant crane control is required from several elevations, the purchaser shall specify such requirements. Methods of raising and lowering the pendant shall be determined and specified by the purchaser, depending on prevailing conditions. Commonly used and readily available lifting and lowering devices consist of spring-operated load balancing reels, or motorized cable reels. In cases where motorized cable reels are used, the pendant shall be suspended directly from the electrical cable, without a strain relief rope.

**5515 Speeds.** For pendant hoist and travel speeds, refer to para. 5334.

### 5520 Load Weighing Devices (Types I, II, and III Hoists)

*(a)* Load weighing devices for a hoist unit shall be provided if requested by the purchaser.

*(b)* Weighing accuracy, location and type of readout, and increments of the readout shall be specified by the purchaser.

*(c)* Refer to Section 6000 for overload devices.

### 5530 Welded Construction

**5531 Type I Cranes.** All welding design and procedures shall conform to the current issue of AWS D1.1. Where special steels or other materials are used, the manufacturer shall provide welding procedures.

**5532 Types II and III Cranes.** Welding shall be in accordance with CMAA 70.

### 5540 Hydraulics (Types I, II, and III Cranes)

*(a)* Hydraulic components and fluids shall be selected to withstand maximum facility lifetime radiation exposure, unless a detailed maintenance program shall be supplied.

*(b)* Critical loads or facility equipment shall be protected from leakage.

*(c)* Commercial industrial hydraulic components in the critical load path shall be selected and rated to not exceed 20% of the average ultimate strength of the material.

### 5550 Ordering Information

Orders for cranes under this Standard shall include the following information.

*(a) Load Spectrum Information.* Refer to para. 5111(a).

*(b) Seismic Consideration for Type III Cranes, If Required.* Refer to para. 5310(b)(3).

*(c) Hoist Speeds.* Refer to para. 5331.1(a).

*(d) Trolley Speeds.* Refer to para. 5332.1(a).

*(e) Bridge Speeds.* Refer to para. 5333.1(a).

*(f) Powered Hook Rotation.* Refer to paras. 5335(a) and (b).

*(g) Bearing Life Computations.* Refer to para. 5455.1(b)(6)(-a).

*(h) Seismic Analysis for Type III Cranes, If Required.* Refer to para. 5483.

*(i) Crane Pendant Mounting.* Refer to para. 5511.

*(j) Motorized Traversing.* Refer to para. 5513.

*(k) Vertical Travel of Control Pendant.* Refer to para. 5514.

*(l) Loading Weighing Devices.* Refer to paras. 5520(a) and (b).

# Section 6000
# Electrical Components



## 6100 GENERAL

*(a)* The specification for each crane shall state which crane classification applies (para. 1130). Types are summarized from para. 1150 as follows:

*(1) Type I Cranes:* single-failure-proof features and seismic considerations

*(2) Type II Cranes:* seismic considerations only

*(3) Type III Cranes:* neither single-failure-proof features nor seismic considerations

*(b)* The specifications for each crane shall include any special requirements for components in accordance with the following:

*(1)* limiting the use of aluminum, zinc, mercury, and other specified materials (para. 6130)

*(2)* painting (para. 6140)

*(3)* life at specified values of radiation exposure (para. 6150)

*(4)* environmental conditions (para. 6160)

*(5)* quality assurance (para. 6170)

*(c)* Generally available equipment that conforms to industry standards, such as those of NEMA, shall be used unless special designs are necessary.

*(d)* The electrical equipment is not required to qualify as IEEE 323 Class 1E.

*(e)* The specification for each Type III crane shall state whether Section 6000 or CMAA 70 is to be invoked for electrical components.

### 6110 Single-Failure-Proof Features (Type I Cranes)

*(a)* The electrical system shall be designed so that it is possible for the operator to stop and hold a critical load regardless of the failure of any single component used in normal operation.

*(b)* In addition to the emergency stop(s) required by para. 6310(c), a minimum of one hard-wired emergency stop shall be provided at ground level (or an appropriate location, e.g., the operating level of the load) that will remove supply power from the crane. The hard-wired emergency stop shall be located in an area that is accessible to crane operation support personnel other than the crane operator.

*(c)* Any inadvertent short circuit or ground shall be considered a single component failure.

*(d)* The avoidance of two-blocking shall be accomplished by the use of single-failure-proof features and shall not rely on any action by the operator. The normal hoist limit switch shall be supplemented by an independent final hoist limit switch operated by the load block to remove power from the hoist motor and brakes.

### 6120 Seismic Considerations (Types I, II, and III Cranes)

*(a) Type I Cranes.* The user shall provide the equipment that shall de-energize the crane power supply in the event of either a safe shutdown earthquake (SSE) or an operational basis earthquake (OBE). The hoist brakes shall be capable of holding the credible load during an SSE or OBE event, as determined in accordance with para. 6422.1(b). All electrical equipment shall remain on the crane during these seismic events.

*(b) Type II Cranes.* Requirements are the same as for Type I cranes, except that the brakes need not be capable of holding the load during a seismic event.

*(c) Type III Cranes.* Seismic considerations are not required for Type III cranes.

### 6130 Limiting the Use of Specified Materials (Types I, II, and III Cranes)

*(a)* If the crane specifications require that the content of certain specified materials for use on a crane be kept at a minimum [para. 1145(a)], but it is not practical to eliminate these specified materials completely, the electrical supplier shall tabulate their weight or surface area or the content of an alloy under the following categories:

*(1) exposed*, as in the head of a master switch

*(2) bare, within a ventilated enclosure*, as in the shaft fan and rotor bars of a ventilated squirrel cage motor

*(3) bare, within a nonventilated enclosure*, as in a totally enclosed nonventilated squirrel cage motor

*(4) covered*, as in insulated windings within a nonventilated motor, lighting transformer, reactor, etc.

*(b)* Galvanized conduit may be used except when specifically prohibited by the crane specifications.

### 6140 Painting (Types I, II, and III Cranes)

When the crane specifications include special painting requirements, the electrical items are exempt from the special painting requirements and shall be furnished with a standard industrial finish [see para. 3230(i)].

### 6150 Radiation Exposure [Types I, II, and III Cranes (Para. 1141)]

*(a)* If the crane is in a location where radiation levels are likely to be a factor in the life of the electrical equipment, the maximum rate of radiation and the total accumulated exposure at the crane elevation shall be stated in the crane specifications.

*(b)* Insulation in rotating machines, brakes, and magnetic device coils may be required to meet an accumulated dosage of $10^7$ rad in 40 yr. Components, such as regulator cards, that can be removed without disconnecting wiring may be required to meet an accumulated dosage of only $10^4$ rad, on the basis that such components can be removed and stored in a location where they will not be exposed to more than normal atmospheric radiation during the long time intervals in which the crane will not operate after the power plant has been placed in service. If the user prefers not to remove the components, it will be permissible to establish a routine maintenance procedure of installing new components after they have accumulated a total exposure of $10^4$ rad.

*(c)* The electrical equipment supplier shall submit data demonstrating that the type of insulation used in the equipment being supplied meets the radiation requirements in the crane specifications.

### 6160 Environmental Conditions (Types I, II, and III Cranes)

*(a)* The electrical equipment specifications shall state environmental conditions to which that equipment may be subjected, e.g.,

*(1)* high humidity or high or low temperatures during prolonged intervals when the crane is in storage or not in use

*(2)* outside service

*(-a)* temporary — during construction only

*(-b)* continuous

*(3)* pressure (para. 1143)

*(-a)* maximum pressure

*(-b)* rate of change in pressure

*(4)* spray [para. 1145(a)]

*(5)* ambient temperature (para. 1142)

*(-a)* rated

*(-b)* short-time exposure to temperatures outside rated ambient range

*(6)* humidity (para. 1144)

### 6170 Quality Assurance (Types I, II, and III Cranes)

There shall be no Quality Assurance Program requirements for activities covered by Section 6000, except for those specifically required in the electrical procurement documents (see para. 2100).

### 6180 Duty Cycle or Duty Class (Types I, II, and III Cranes)

The specifications shall state the duty cycle requirements in accordance with para. 6418.2 or the electrical duty class that applies to each motion as determined by Table 6472.3-1. If the crane is to be used for construction purposes, the duty cycles or classes required for that service shall be specified. In addition, any requirements for prolonged operation at reduced speed shall be specified.

## 6200 WIRING MATERIALS AND METHODS (TYPES I, II, AND III CRANES)

### 6210 General

*(a) Applicable Standards*:

*(1)* National Electrical Code (NEC), Article 610, "Cranes and Hoists")

*(2)* American Society for Testing and Materials (ASTM) B8 and B174

*(3)* National Electrical Manufacturers Association (NEMA) Pub. No. ICS 1

*(b)* The provisions of this Section apply to interconnecting wiring both within and external to control panel enclosures. It does not apply to wiring that forms an integral part of equipment such as motors, individual control components — for example, contactors, transformers, and relays — and electronic control subassemblies.

*(c)* The complete raceway system including wire shall be assembled on the crane at the crane manufacturer's facility. Where disassembly is necessary for shipment, components shall be match-marked for ease of field erection. Where any portion of a raceway run must be disconnected or dismantled to permit shipment, the wire shall not be pulled through that raceway during shop assembly. Wire not pulled shall be cut to approximate length and bound in coils marked for the circuit for which it applies.

*(d)* The wiring system shall meet the applicable requirements of NEC, Article 610.

*(e)* For Types I and II cranes, the raceway system shall be secured and braced to withstand forces due to specified seismic events.

*(f)* For cranes located inside the containment, consideration shall be given to rapid pressure changes as required by the specification. Pressure relief openings in electrical enclosures shall be provided where necessary to equalize these pressures.

### 6220 Materials

#### 6221 Conductors

*(a)* Individual conductors including those in multiconductor cables shall have a maximum operating temperature rating not less than 167°F.

*(b)* Multiconductor cable shall be permitted in wiring the crane. Uses of the cable shall comply with the National Electrical Code. Multiconductor cable used in flexing service shall be Type SO, Type W, or a purchaser-approved alternative.

(c) All control conductors and cables used with AC inverter type controls and having operating voltages less than 110 V shall be of a shielded type.

(d) Minimum sizes of conductors shall be as follows:

(1) No. 14 AWG for power and lighting circuits

(2) No. 16 AWG for control circuits

(3) No. 18 AWG for electronic circuits

(e) Conductors shall be annealed copper with minimum stranding as follows:

(1) ASTM B8 Class B for nonflexing service

(2) ASTM B174 Class K for flexing service

(f) Color coding, if specified, shall be per NEMA Part ICS 1-112.64.

#### 6222 Raceways

(a) Wiring external to control panel enclosures or assemblies of control panels with integral raceways shall be installed in rigid metal conduit except as otherwise permitted in this Section or as specifically approved by the purchaser.

(b) Short lengths of open conductors shall be permitted at collectors and within enclosures or guards for resistors, reactors, and transformers.

(c) Conduit smaller than $\frac{3}{4}$ in. diameter trade size shall not be used.

(d) An electrically continuous system, either liquid-tight or properly drained, shall be used. For a liquid-tight system, gaskets, bushings and seals shall be used where appropriate.

(e) Flexible metal conduit may be used to enclose conductors to stationary or infrequently moved devices such as motors, brakes, master switches, and limit switches, or to equipment subject to vibration. The length of flexible conduit shall not exceed 3 ft.

(f) Connections to moving parts (e.g., bridge to trolley, bridge or trolley to pendant push-button station) may be made by flexible cable not enclosed in conduit.

(g) Conduit shall be rigidly attached to the crane by conduit supports. Welding of conduit shall not be permitted. Conduit supports may be welded to structural members; welding shall be in accordance with para. 4230.

### 6230 Wiring Methods

(a) All conductors shall be identified at each termination by marking with a number to correspond to the schematic diagram.

(b) Conductors shall be run from terminal to terminal without splices except at devices with integral leads or within junction boxes where connections shall be made with bolted ring-type pressure connectors.

(c) Pressure-type connectors shall be provided on all wires connected to terminals not equipped with means for retaining conductor strands.

(d) All external conductors for control circuits shall be routed through terminal blocks with no more than two conductors terminated at each connection point.

(e) Panel wiring shall be neatly routed and supported in a manner that will not interfere with inspection and maintenance of devices.

(f) Control conductors external to AC inverter controls that connect to components subject to detrimental effects, due to electromagnetic interference induced in the conductor from other conductors or electrical equipment, shall be of a design or installed in such a manner that prevents such effects. Examples include the following:

(1) Use individually shielded twisted pair conductors for tachometer or encoder connections.

(2) Route such conductors through a separate conduit.

(3) Refrain from splicing connections.

## 6300 PERFORMANCE SPECIFICATIONS (TYPES I, II, AND III CRANES)

### 6310 General

(a) The rated load speeds recommended in paras. 5331, 5332, and 5333 are normal speeds based on the rated capacity of the crane. The characteristics of drive systems can vary widely with respect to speeds at other than rated load and with respect to lowering speeds at any load. Drive systems shall be chosen to conform to any speed–load constraints stated in the specifications.

(b) If more than one control station is required (e.g., cab control and radio remote control), performance criteria for each of the stations shall be specified.

(c) An emergency stop shall be provided on each operator control device (cab control, pendant station, radio control, etc.) and shall be within reach of the operator in any operating position. The emergency stop shall open or de-energize a power device that is not required to open and close during normal run–stop operations. A fail-safe circuit shall be used to implement this provision.

### 6320 Hoist

(a) Hoist design rated load speed and speed load characteristics shall be in accordance with para. 5331. The corresponding rated load lowering speed shall not exceed 125% of the hoisting speed.

(b) The maximum lowering speed with 125% capacity test load shall not exceed the maximum lowering speed with rated load by more than 10%.

(c) Auxiliary hoists on Type I cranes shall meet the requirements of single-failure-proof design if they handle critical loads. If, through administrative control or other means, assurance is provided that no critical load will be handled by an auxiliary hoist, it shall meet the performance requirements of hoists for Type II cranes.

(d) The hoist drive characteristics shall be such that the peak acceleration and deceleration of the load does not exceed 5 $ft/sec^2$.

*(e)* On Type I crane hoists that handle critical loads, control with a high-speed, light-load feature shall be equipped with a means of locking out this feature when handling a critical load.

*(f)* The stopping distance for various hoist designs is variable. On Type I crane hoists that handle critical loads, the stopping distance shall not exceed 5 in. while lowering the maximum critical load at its maximum speed unless specified otherwise by the purchaser.

### 6330 Bridge

*(a)* The bridge design rated load speed and speed load characteristics shall be in accordance with para. 5333.

*(b)* Bridge acceleration rates with rated loads should be limited to the values shown in Table 6472.2-2. The operator should have control of deceleration to minimize load swing and avoid wheel slip. In emergency situations such as emergency stop, overspeed, and limit trips, the deceleration rate may exceed the selected acceleration rate and normal deceleration rates.

*(c)* Type I crane bridge control with a high-speed, light-load feature shall be equipped with a means of locking out this feature when handling a critical load.

*(d)* When specified, a drift point in the control system shall be provided for the lowest operating point of the selected speed mode (i.e., normal, inching, etc.).

### 6340 Trolley

*(a)* The trolley design rated load speed and speed load characteristics shall be in accordance with para. 5332.

*(b)* Trolley acceleration rates with rated load should be limited to the values shown in Table 6472.2-2. The operator should have control of deceleration to minimize load swing or wheel slip. In emergency situations such as emergency stop, overspeed, and limit trips, the deceleration rate may exceed the selected acceleration rate and normal deceleration rates.

*(c)* Type I crane trolley control with a high-speed, light-load feature shall be equipped with a means of locking out this feature when handling a critical load.

*(d)* When specified, a drift point in the control system shall be provided for the lowest operating point of the selected speed mode (i.e., normal, inching, etc.).

## 6400 COMPONENT SELECTION (TYPES I, II, AND III CRANES)

### 6410 Controllers

#### 6411 General

**6411.1 Applicable Standards.** Controllers shall conform to NEC, ASME B30.2, and NEMA Parts ICS 2-213, 3-442, 3-443, and 6-110.

**6411.2 Voltage Variations.** At an ambient temperature between 32°F and 100°F, the controller shall be capable of operating at a deviation not more than 10% from rated nameplate value, except that for systems using semiconductor power converters, the deviation may be limited to not more than 10% above or 5% below rated nameplate value.

**6411.3 Ambient Temperature.** Ambient temperature shall be above 32°F but shall not exceed 100°F. If the specifications state that the equipment is to be operated at ambient temperatures outside this range, the control manufacturer shall be consulted.

**6411.4 Enclosure Requirements.** The enclosures, if required, shall be in accordance with NEMA, Part ICS 6. Consideration shall be given to high humidity or washdown locations, pressure equalization requirements, and outdoor usage requirements when enclosures are selected.

**6411.5 Protection Against Condensation.** Unless otherwise specified, enclosed control panels in high humidity locations shall have space heaters to reduce the possibility of condensation. If heaters are used, they should be energized when the crane is to be out of service for more than 8 hr.

**6411.6 Hoists**

*(a)* All hoists shall be provided with controlled lowering capable of meeting the performance specifications in para. 6300.

*(b)* Hoisting shall take place only when the master switch is in a hoisting position. For all loads up to rated load, lowering shall take place only when the master switch is in a lowering position.

*(c)* In the event of an emergency stop or other emergency conditions, the two brakes required by para. 6422.1(a) shall be de-energized without intentional time delay.

*(d)* Both sides of shunt brake coil circuits on hoists shall be opened when the brake is de-energized.

*(e)* Type I hoists shall be provided with an indication at the operator's control location to confirm the selected direction of load movement. This indication shall be taken from the drive train motion and electrically separated from the control circuit.

#### 6412 Type Selection.

The type of control supplied shall result in operation complying with the performance specifications in para. 6300, taking into consideration any supplemental requirements stated in the crane specifications. Any of the following types of control that will meet those requirements shall be supplied.

#### 6413 Constant Potential DC

**6413.1 Hoist**

*(a)* Series motors and series brake(s) shall be used. Control shall provide dynamic braking lowering and include a spring-closed off position dynamic braking contactor to provide self-excitation of the motor series field in the lowering direction.

*(b)* For Type I hoists, provision shall be made to comply with the maximum hoisting and lowering speed limitations when handling critical loads, as specified in paras. 5331 and 6320, with the overspeed protection specified in para. 6444. Control shall provide that the series brakes cannot be energized unless there is a path for braking current in the motor armature. These provisions are to include the following:

*(1)* A double set of conductors and collectors shall be provided in the part of the armature lowering circuit not connected to the series field series brake circuit.

*(2)* Any resistance in the armature circuit when lowering shall have a continuous rating equal to the motor rated current.

*(3)* If the dynamic lowering contactor in the armature circuit is not closed when the master switch is in any lowering position, the spring-closed emergency dynamic braking contactor shall remain closed.

*(4)* Temperature-sensitive devices in the motor shall warn the operator when the temperature approaches a value that could be injurious to the insulation.

**6413.2 Travel.** The travel control shall be the reversing, contactor-resistor type with controlled plugging.

### 6414 Constant Potential AC

#### 6414.1 Hoist

*(a)* Speed control may be achieved by the following:

*(1)* contactors and resistance in the secondary of the wound rotor motor

*(2)* static power devices such as saturable reactors or thyristors in the secondary of the wound rotor motor

*(3)* contactor(s), and resistance in the primary of a squirrel cage motor

*(4)* an electrical load brake

*(5)* a combination of these methods

*(b)* Type I cranes shall be provided with the following:

*(1)* open and reverse phase protection

*(2)* a circuit to ensure that power is applied to the hoist motor(s) before the brakes (para. 6422) are released

*(3)* a circuit to de-energize the hoist motor and to set the brakes if the electrical load brake is not energized sufficiently to limit the speed when the control is in a position requiring electrical load brake torque

*(4)* temperature-sensitive devices in motors and load brakes to warn the operator when the temperature of a motor or load brake approaches a value that could be injurious to the insulation or could interfere with meeting the performance specifications in para. 6300

#### 6414.2 Travel

*(a)* Speed control may be achieved by the following:

*(1)* contactors and resistance in the secondary of the wound rotor motor

*(2)* static power devices such as saturable reactors or thyristors in the secondary of the wound rotor motor

*(3)* contactor(s) and resistance in the primary of a squirrel cage motor

*(4)* an electrical load brake

*(5)* a combination of these methods

*(b)* Control shall include controlled plugging.

### 6415 Adjustable Voltage DC

*(a)* Control shall include a contactor that will disconnect power to any drive not in use.

*(b)* Control shall include controlled electrical braking and may include a feature that will keep the electrical braking circuit energized until the motor approaches zero speed when the operator wishes to stop.

*(c)* A contactor shall be provided in the DC motor armature circuit if a generator is the source of DC power, but the contactor can be in either the AC or DC power circuit if static power conversion is used.

*(d)* Motor field loss protection shall be provided.

#### 6415.1 Hoist (15)

*(a)* Hoists with static power supplies shall include means to automatically remove power from the motor and to set the brake(s) if the drive does not develop braking torque as required when lowering a load or when the operator attempts to reduce speed.

*(b)* In addition to (a) above, hoists handling critical loads on Type I cranes shall be provided with the following:

*(1)* provisions to maintain proper field excitation to comply with the speed limitation in para. 6300. Activation of this speed-limiting feature shall be the responsibility of the designated person responsible for moving critical loads [see para. 6320(e)].

*(2)* a protective circuit to ensure current flow in motor armature circuit before brakes can be energized (current check circuit or torque proving circuit).

*(3)* a temperature-sensitive device in the motor to warn the operator when temperature approaches a value that could be injurious.

*(4)* temperature-sensitive devices in or near the resistors that are required to absorb "pump back energy" to warn the operator when the resistors approach a value that could cause them to fail.

*(c)* Hoists with series motors and brakes shall provide dynamic braking lowering and include a spring-closed off position dynamic braking contactor to provide self-excitation of the motor series field in the lowering direction.

#### 6415.2 Travel

*(a)* Field loss protection is not required on travel drives having motor field reversing and designed to permit coasting.

*(b)* When two or more motors connected in parallel are used, provision shall be made at the control panel to permit isolating any motor and to continue operation

with the remaining motor(s) with normal protection features, if agreed to by the user, crane builder, and electrical equipment supplier(s).

#### 6416 Adjustable Voltage AC

*(a)* Speed control may be achieved by static power devices such as saturable reactors or thyristors in the primary circuit.

*(b)* Control shall include controlled electrical braking and may include a feature that will keep the electrical braking circuit energized until the motor approaches zero speed when the operator wishes to stop.

##### 6416.1 Hoist

*(a)* The secondary may have a fixed impedance, although a means may be provided to increase the resistance in the secondary of the wound rotor motor for operation at reduced speeds for prolonged periods or if frequent deceleration is anticipated.

*(b)* An electrical load brake may be used with the above.

*(c)* Type I cranes shall have protection as required in para. 6414.

##### 6416.2 Travel

*(a)* The secondary may have a fixed impedance, although a means may be provided to increase the resistance in the secondary to permit prolonged operation at reduced speed or to reduce motor heating when plugging.

*(b)* When two or more motors are used, provision shall be made at the control panel to permit isolating any motor and to continue operation with the remaining motor(s) with normal protection features if agreed to by the purchaser, crane builder, and electrical equipment supplier(s).

#### 6417 AC Variable Frequency

*(a)* Control shall consist of a variable frequency drive (VFD) with a full load ampere (FLA) rating equal to, or greater than, the FLA of the corresponding motor(s).

*(b)* Control shall include, as a minimum, the following protective features:

*(1)* output phase loss
*(2)* under voltage
*(3)* over voltage
*(4)* motor thermal overload
*(5)* VFD overheat

*(c)* Control shall provide a control braking means using dynamic braking or line regeneration.

*(d)* Control shall have a minimum of 150% overload capability for 1 min.

*(e)* The cable power supply and electronic equipment shall be protected from detrimental effects due to harmonic and EMI/RFI emissions produced by inverters.

##### 6417.1 Hoist

*(a)* The VFD control shall incorporate a speed feedback device to sense loss of speed control during any motor operating condition. Hoists with mechanical load brakes are exempt from this requirement.

*(b)* Control dynamic braking shall be sized for a minimum of 150% of motor full load torque, but *shall not, under any circumstances, be less than* the torque (or corresponding current) limit setting of the VFD in the hoisting direction.

NOTE: Control dynamic braking on hoists with mechanical load brakes shall be sized such that the combined retarding torque in the lower direction of the dynamic braking and the mechanical load brake are equal to or greater than the torque (or corresponding current) limit setting of the VFD in the hoisting direction.

*(c)* Control shall sense sufficient motor torque (or corresponding current) before releasing holding brake(s) (i.e., torque proving). Hoists with mechanical load brakes are exempt from this requirement.

*(d)* In lieu of the design tolerance para. 5331.1(b), control shall maintain speed control under all motor operating conditions to within ±5% of the commanded speed.

*(e)* If specified by the owner, control shall be capable of operating at higher than base speed as a function of load (constant horsepower operation) for loads less than 100% rated load.

*(f)* Type I cranes shall have controls with the following capabilities:

*(1)* A warning device shall be provided to warn the operator of a pending motor overheat condition.

*(2)* A warning device shall be provided to warn the operator that the dynamic braking resistors have overheated.

**6418 Sizing Procedure.** Control ratings shall be in accordance with NEMA standards with the following qualifications.

**6418.1 Hoists That Handle Critical Loads on Type I Cranes.** As a minimum, contactor, resistor, thyristor, and reactor ratings shall have a continuous rating equal to the greater of the steady state currents in those devices when hoisting or lowering rated load at full speed. Accelerating resistors, if used, shall be NEMA Class 90 (see NEMA, Part ICS 2-213).

Mechanical load brakes shall not be used as the control braking means.

**6418.2 Types I, II, and III Cranes.** The crane specifications shall state all required repetitive duty cycle operations or prolonged operations in terms of load, distance, speed, time, and frequency of repetition. All the control components (including the control braking means) shall be checked by the supplier to ensure that they are adequate for that specification.

### 6420 Friction Brakes

**6421 General (Types I, II, and III Cranes).** This section covers the requirements for friction-type brakes for purposes of holding, emergency, parking, and service brakes.

**6421.1 Applicable Standards.** The brake selections shall be in accordance with the definitions and brake requirements of ASME B30.2, with further specific requirements as covered by this section and para. 6100.

**6421.2 Brake Operation.** The brakes shall have a thermal capacity for the frequency and duration of the specified operations to prevent overheating of the brake wheel, disks, brake linings, and other parts. Brake manual release mechanisms shall be furnished to permit drive movement during power outages, and shall be of the manual-release self-reset type, operative only when held manually in the release position. Drag brakes shall not be used.

**6421.3 Electric Brakes**

*(a)* The electrical operating and excitation system shall have a thermal rating for the frequency and duration of the specified operations, and the thermal time rating shall equal or exceed the corresponding drive motor time rating.

*(b)* Brakes with DC shunt coils shall release at 80% and operate without overheating at 110% of the rated excitation system voltage. Whenever DC shunt coils are used on hoist brakes, the combination of the brake coil and excitation system shall result in a quick response of brake release and set.

*(c)* Brakes with AC coils shall release at 85% and operate without overheating at 110% of rated excitation system voltage.

**6421.4 Brake Lining, Friction Material.** Brake lining material shall permit brakes to maintain adequate torque for the specified environmental conditions and at the lining temperatures resulting from the frequency and duration of the specified operations. Manual or automatic means shall be provided to adjust the brake operating mechanism to compensate for the effect of lining wear.

**6422 Hoist Brakes (Types I, II, and III Cranes)**

(15) **6422.1 Hoists That Handle Critical Loads on Type I Cranes**

*(a)* The braking system shall comply with at least one of the following:

*(1)* Three or more holding brakes shall be provided for stopping and holding the load, such that after failure of any one holding brake or hoist machinery component, at least two holding brakes remain available for emergency load lowering.

*(2)* Two brakes, each capable of stopping and holding the load, may be provided if one of these acts directly on the wire rope drum shell or a flange or disc attached thereto, is not the primary stopping and holding brake, and does not set prior to the wire rope drum coming to a complete stop during normal operation. The brake acting on the drum must have sufficient thermal capability to permit emergency lowering of rated load from normal high hook position to normal low hook position at maximum design full-load lowering speed in one continuous operation, and must have a torque-modulating method of manual release.

*(3)* Two brakes, each capable of stopping and holding the load, may be provided if the hoist also has a mechanical or electrical control braking means that prevents the rated load from lowering faster than design maximum lowering speed with power off. The control braking system must be capable thermally and in all respects of lowering rated load from normal high hook position to normal low hook position in one continuous operation. One of the two stopping and holding brakes and the control braking means must remain effectively connected to the hoist drive train after failure of the other brake or any component of the hoist machinery.

Each holding brake shall have a torque rating not less than 125% of the full (rated) load hoisting torque at the point of brake application, and shall be capable of stopping the lowering movement within amounts of motion wherein damage to load or facility would not occur. A maximum lowering distance of 3 in. is recommended. The design of the brakes and the arrangement of the braking system shall enable recovery from an inoperable brake by repair of the brake in place or replacement of the brake, with rated load on the hoist, or by an alternative recovery means acceptable to the purchaser.

*(b)* Determination shall be made that if the holding brakes are mounted and adjusted, and linings run in properly for the torque settings required in (a) above, the brake system shall be capable of stopping and holding the credible critical load during an SSE or OBE event. The values used for this determination shall be based on the maximum acceleration forces at the brake(s) computed for the crane SSE or OBE specifications, and the total torque required on the brake system to hold the credible critical load.

*(c)* Provision shall be made for emergency lowering of the critical load by an alternative means of operation of the holding brakes. The alternative release mechanisms shall permit control of the braking torque and shall also provide the ability to restore the "brake set" condition promptly, thereby allowing the operators of the alternative release mechanisms to control the lowering speed. A device for indicating lowering speed shall be located at the emergency release station. Intermittent lowering shall be allowed to provide time for cooling the brake mechanism to obtain adequate heat dissipation and to prevent reduction in braking torque that can occur as the result of excessive heat.

*(d)* The detrimental effects of radiation exposure on the brake linings shall be determined and a routine replacement procedure established so as to maintain an adequate torque.

*(e)* Each holding and emergency brake shall be independently actuated by at least two contactors. When possible, each contactor coil should be controlled by independent controller outputs. If only one controller output exists, the contactor coils may be wired in parallel. The two sets of contacts shall be wired in series between the power supply and each brake coil. Hoists with DC Series brakes are exempt from this requirement.

(15) **6422.2 Hoists on Types II and III Cranes and Hoists That Do Not Handle Critical Loads on Type I Cranes.** At least one holding brake shall be provided. Each brake shall have not less than the following percentage of the rated load hoisting torque at the point where the brake(s) is applied:

*(a)* 125% when used with a control braking means other than mechanical

*(b)* 100% when used with a mechanical control braking means

*(c)* 100% if two holding brakes are provided

Holding brakes that are controlled by variable frequency controls shall be actuated by at least two independent contactors. When possible, each contactor coil should be controlled by independent controller outputs. If only one controller output exists, the contactor coils may be wired in parallel. The two sets of contacts shall be wired in series between the power supply and each brake coil. Hoists with mechanical load brakes or DC series brakes are exempt from this requirement.

### 6423 Trolley and Bridge Brakes (Types I, II, and III Cranes)

#### 6423.1 Application

*(a)* All travel drives shall have service braking means.

*(b)* When a friction brake is used for service braking, the brake torque shall be sufficient to stop the drive within a distance in feet equal to 10% of the rated load speed in feet per minute when traveling at full speed with rated load.

*(c)* Emergency brakes shall be of the friction-type that will set automatically upon power failure and shall be capable of stopping the drive within the distance specified in (b) above.

*(1) For Type I Cranes.* Emergency and parking brakes shall be provided for the travel drives. Parking brakes shall be automatically applied and shall be provided with time delay relays, if necessary, to eliminate interference with service brake operation.

*(2) For Types II and III Cranes.* Emergency brakes shall be provided when required by the specification.

*(d)* Any combination of service, emergency, and parking functions may be performed by a single friction brake, provided the emergency and parking functions can be obtained without having power available.

#### 6423.2 Trolley Brake Sizing Procedures

*(a)* On cab-operated cranes, trolley service braking shall be provided as required by para. 6423.1(a) with sufficient torque to satisfy the deceleration requirements of para. 6423.1(b).

*(b)* On floor-, remote-, or pulpit-operated cranes, trolley emergency brakes with torque rating to satisfy the deceleration requirements of para. 6423.1(b) shall be provided.

#### 6423.3 Bridge Brake Sizing Procedures

*(a)* On cab-operated cranes with cab on bridges, bridge service braking shall be provided with sufficient torque to satisfy the deceleration requirements of para. 6423.1(b).

*(b)* On cab-operated cranes with cab on trolley, bridge emergency brake(s) with torque rating to satisfy the deceleration requirements of para. 6423.1(b) shall be provided in addition to bridge service braking.

*(c)* On floor-, remote-, or pulpit-operated cranes, bridge emergency brake(s) shall be provided with torque rating to satisfy the deceleration requirements of para. 6423.1(b).

## 6430 Disconnecting Means

### 6431 General (Types I, II, and III Cranes)

**6431.1 Applicable Standards.** All crane disconnecting devices shall be selected and installed as required by NEC Article 610; ASME B30.2, Section 2-1.10.5; and NEMA Parts ICS 3-442 and 3-443.

### 6432 Main Disconnects

**6432.1 Runway Disconnects (Types I, II, and III Cranes).** A circuit breaker or motor circuit switch selected in accordance with NEC 610-31 shall be provided in the leads to the runway conductors.

**6432.2 Crane Disconnect (Types I, II, and III Cranes).** All cranes shall have a main line disconnect in accordance with NEC 610-32, and shall be rated in accordance with NEC 610-33 plus any additional continuous load. This disconnect shall be enclosed as required by environmental conditions. Unless overcurrent protection is provided by other means, it shall be incorporated in this main line disconnect and the user shall specify available rms symmetrical short circuit current.

**6432.3 Motor Power Circuit Disconnecting Device (Type I Cranes).** A device shall be furnished to open the power circuit to all crane drive motors. This device shall be capable of being opened from all operator stations. The device shall open automatically upon failure and shall be unable to reclose until a reset function is performed.

The minimum size of this device shall be not less than that required by NEC 610-33. The opening of this device shall cause the holding and emergency brakes to set.

**6432.4 Motor Power Circuit Disconnecting Device (Types II and III Cranes).** Unless a device (para. 6432.3) is supplied, the crane disconnect (para. 6432.2) must be accessible for opening by the operator and must be connected in a way that the functional protection required by para. 6432.3 is provided.

**6432.5 Motion Power Disconnecting Devices (Type I Cranes).** Control shall include a separate disconnecting means for each crane motion.

**6433 Auxiliary Disconnects (Types I, II, and III Cranes).** The crane manufacturer shall provide disconnecting means in the form of fused safety switches or circuit breakers as required by NEC to protect and disconnect all auxiliary equipment supplied by the manufacturer or specified by the purchaser. Auxiliary equipment may include

*(a)* lighting
*(b)* signal systems
*(c)* heating/ventilating/air conditioning
*(d)* convenience outlet
*(e)* special devices when applicable

Ground fault circuit interrupters, if required for convenience outlets, shall be a part of the user's specifications.

### 6440 Limit Devices

(15) **6441 General (Types I, II, and III Cranes).** A *limit device* is defined as a switch or sensing system to provide control functions on the crane. This paragraph includes requirements for control limit devices that activate when the normal operating envelope has been reached and safety critical limit devices that indicate malfunction, failure, or inadvertent operator action.

Additional limit device requirements not addressed in this section shall be incorporated in the specifications. AC cranes shall have phase reversal protection.

**6441.1 Type I Crane Safety Critical Limit Devices.** This paragraph includes additional requirements for the following safety critical limit devices:

*(a)* final hoist overtravel
*(b)* hoist overspeed
*(c)* hoist overload
*(d)* hoist unbalanced load
*(e)* hoist drum rope mis-spooling

*(1) Manual Reset.* When a safety critical limit device is activated, a manual reset is required. This may be accomplished by means of a key switch on the crane or some other administrative control that will prevent the crane operator from resetting the affected function before a person knowledgeable in the crane control system shall determine and correct the cause of device activation.

*(2) Safety Critical Limit Devices.* Safety critical limit devices shall be in addition to and separate from the limiting means or control devices provided for operation unless independently monitored.

### 6442 High Limits

**6442.1 Type I Cranes.** All hoists, including hoists that do not handle critical loads, shall include two separate overhoist limit switch systems as required in paras. 6442.1(a) and (b).

*(a) First High Limit.* The first upper hoisting limit shall be a control circuit device such as a geared-type, weight-operated, or paddle-operated switch. Actuation of this switch shall result in the removal of power from the motor and setting the hoist brakes. The operator may lower or back out of this tripped switch without further assistance.

*(b) Final Overtravel High Limit.* The second upper hoisting limit shall be actuated by the lower block by means of a weight or paddle, and shall operate through a separate control circuit from the first high limit switch (or may interrupt the motor leads directly) to cause the removal of power to the hoist motor and set the hoist brakes. Actuation of this limit switch shall prevent further hoisting or lowering.

**6442.2 Types II and III Cranes.** One high limit switch shall be provided.

**6443 Hoist Low Limits (Type I Cranes).** Hoists that handle critical loads shall include two separate low limits, as required in paras. 6443.1 and 6443.2.

**6443.1 First Low Limit (Type I Cranes).** Each hoist that handles critical loads shall include an overtravel low limit switch. This switch may be of the control circuit type. Actuation of this switch shall stop the lowering motion and set the hoist brakes. The operation of this switch shall not prevent hoisting.

**6443.2 Final Overtravel Low Limit (Type I Cranes).** Hoists that handle critical loads shall include, in addition to a first low limit as specified in para. 6443.1, a final lowering limit switch of the control circuit type that shall be mechanically and electrically independent of the first low limit. Operation of this limit switch shall de-energize a power device other than the device operated by the first low limit to interrupt all power to the hoist motor and the hoist brakes. Actuation of this limit switch shall prevent further lowering or hoisting. When this occurs, a person knowledgeable in the hoist control system shall determine and correct the cause of tripping of the final low limit switch. That person shall direct the raising out of the final low limit after establishing a back out mode that shall prevent further lowering. The first low limit shall be tested for proper operation before making any additional lifts.

**6443.3 Low Limits (Hoists on Types II and III Cranes and Hoists That Do Not Handle Critical Loads on Type I Cranes).** A low limit shall be furnished

*(a)* as recommended by ASME B30.2, para. 2-1.10.5(e), when specified in the crane specifications, or
*(b)* when required by ASME B30.2, para. 2-1.11.3(c)(1)

(15) **6444 Hoist Overspeed Limits (Type I Cranes)**

*(a)* Hoists that handle critical loads shall include an overspeed limit device (switch or sensing system). When handling a critical load, hook speeds over 115% of the design critical load lowering speed shall actuate this device, causing all holding brakes to set without intentional time delay. Operation of this device may also initiate any control braking means normally used for stopping of the load. It shall be necessary to position the hoist motion master switch in the neutral or off position and to manually reset the overspeed limit device (or the overspeed circuit) before operation can be resumed.

*(b)* The overspeed device shall be located so that it monitors drum rotation irrespective of a single failure in the drive train.

*(c)* On hoists that provide high-speed, light load features, provisions may be made to permit override of this overspeed limit device when handling noncritical loads.

**6445 Hoist Load Limits**

**6445.1 Overloading (Types I, II, and III Cranes).** A load sensing system shall be provided for Type I cranes to protect against overload. This system shall detect physical strain by direct measurement within the hoist load path and shall be powered from the control circuit of the associated drive. The high-load limit (system set point) shall prohibit hoisting but permit lowering. The sensing system shall be set at a maximum 125% of the rated load unless analysis determines that greater than 125% is acceptable. If it is necessary to change or bypass the high-load limit, the procedure shall be included in an administrative control program.

A load sensing system is not required for Types II and III cranes.

**6445.2 Unbalanced Load Limits (Type I Cranes).** Dual reeved hoists that handle critical loads on Type I cranes shall include a device to detect excessive movement of the equalizer mechanism. Tripping of this device shall initiate a flashing warning light visible to the crane operator and shall shut down the hoisting motion. Means shall be provided to allow the use of hoist under administrative control. Reeving shall then be corrected before returning hoist to additional service.

**6446 Hoist Drum Rope Mis-Spooling Limits**

**6446.1 Hoist Drum Rope Mis-Spooling Limits (Type I Cranes).** Hoists that handle critical loads shall include a hoist drum rope mis-spooling limit switch to detect improper threading of hoist rope in hoist drum grooves.

Actuation of this switch shall result in removal of power from the hoist motor and setting the hoist holding brakes.

Actuation of this limit device shall prevent further hoisting or lowering until a key-operated bypass is used to enable lowering out of the mis-spooled condition, with further hoisting prevented until the mis-spooled condition is corrected. The limit shall be tested for proper operation before making any additional lifts.

**6446.2 Hoist Drum Rope Mis-Spooling Limits (Types II and III Cranes).** Hoist drum rope mis-spooling limits shall be furnished in accordance with para. 6446.1 when so specified in the crane specifications.

**6447 Bridge and Trolley Overtravel Limits (Types I, II, and III Cranes).** Bridge and trolley overtravel limits shall be furnished when specified. Refer to paras. 5131(b) and 5459.1(d) and (e).

**6448 Restricted Handling Path (Type I Cranes).** On some Type I cranes, it may be essential that the hook follow a restricted critical load handling path. The requirements for such paths vary widely with individual nuclear plant designs. The crane specifications shall designate the required accuracy, positions where redundancy is required, and any test and signal system required.

**6450 Master Switches, Pushbuttons, and Radio Controls (Types I, II, and III Cranes)**

**6451 General**

**6451.1 Applicable Standards.** All such devices shall comply with ASME B30.2.

**6452 Contact Ratings.** Contacts in master switches, pushbuttons, and radio control interface panels should be heavy duty rated per NEMA ICS 2-125. See Table 1 or 2, for appropriate application. Multispeed pendant pushbuttons shall be rated per NEMA A150 or N300.

**6453 Voltage Ratings.** The voltages in pushbuttons, master switches, and similar control circuit devices shall not exceed 150 V AC or 300 V DC.

**6454 Radio Controls.** If radio control of cranes in the containment area has been provided for construction operation, that equipment shall be removed before the crane is certified for service in the operating plant unless the effect of radio transmission on reactor plant instrumentation has been analyzed.

**6455 Multiple Control Stations.** On cranes and related equipment provided with multiple control stations, electrical interlocks shall be included in the system to permit operation from only one station at a time. *Electrical interlock* is defined as effective isolation of the control circuits with the use of rotary switch contacts, relay contacts, or similar equipment. Emergency functions shall remain operable from all hardwired control stations.

**6460 Auxiliary Equipment (Types I, II, and III Cranes)**

**6461 General.** Auxiliary electrical equipment shall be provided as specified. All necessary mounting hardware, wiring, disconnecting means, and associated control means shall be included. For Types I and II cranes, all auxiliary equipment shall be mounted and secured so as not to become dislodged or to fall from the crane during a seismic event.

**6462 Light Fixtures.** Light fixtures shall be as specified in the crane specifications.

**6463 Signal Systems.** Signal systems shall be as specified in the crane specifications.

**6464 Heating, Ventilating, and Air Conditioning.** Heating, ventilating, and air conditioning shall be as specified in the crane specifications.

**6465 Convenience Outlets.** Convenience outlets shall be as specified in the crane specifications.

**6466 Power for Auxiliary Equipment.** Unless otherwise specified, power for all auxiliary equipment shall be from a separate protected branch circuit connected ahead of the main drive motor disconnecting means, so that power is available to auxiliary equipment when the main drives are shut down.

**6467 Wiring for Auxiliary Equipment.** All wiring for auxiliary equipment shall be in accordance with NEC. All equipment shall be grounded.

## 6470 Motors (Types I, II, and III Cranes)

### 6471 General

*(a) Direct Current Motors.* DC motors shall be in accordance with either NEMA MG-1 or AISE TR No. 1.

*(b) Alternating Current Motors*

*(1) Definite Purpose Inverter-Fed Motors.* AC squirrel cage motors applied to variable frequency drives (VFDs) shall be specifically designed for inverter duty and shall conform to NEMA MG-1, Part 31, or other standard as approved by the owner.

*(2) Definite Purpose Wound Rotor Induction Motors.* AC wound rotor motors shall conform to NEMA MG-1, Part 18.501 through 18.520.

*(3) Other AC Motors.* All other AC motors not already described shall conform to NEMA MG-1.

*(c)* All AC or DC motors shall have enclosures and time ratings as required for the duty and environmental conditions.

### 6472 Motor Size Selection, AC or DC

*(a)* The motor size selection is determined by the duty class or duty cycle for each motion, not the Type I, II, or III crane classification. Because of the large variety of crane drives available and the difference in the effects of those drives on the thermal adequacy of the motors under consideration, any attempt to develop a procedure for selecting motor ratings becomes quite involved. Whenever possible, the specifications should indicate the most severe repetitive duty (or duties) that each motor will be required to meet, especially including intervals of slow speed operation, if any. The supplier shall be responsible for selecting ratings that will meet the specified duty with the type of control specified. In the absence of duty cycle requirements, the specifications shall clearly identify the duty class to be used for each motion in the procedure described herein. The rating of auxiliary devices (such as mechanical or electrical load brakes) must also be selected to meet the specified duty or duty class.

*(b)* For ambient temperatures above 100°F, the motor design (frame size, insulation class, enclosure, and ventilation) shall be selected to compensate for the increased ambient so the total insulation temperature will not exceed the value allowed by NEMA for the selected insulation class. For example, in a 140°F ambient, a motor with Class F insulation rated at Class B rise might be selected.

**6472.1 Hoists.** The hoist motor shall be so selected that its nameplate rating will not be less than that given by the following formula:

$$hp = K_S WV/33{,}000E \quad (1)$$

where

$E$ = the product of the gearing efficiency and the reeving efficiency (see para. 5429 for reeving efficiency)
$hp$ = horsepower
$K_s$ = service factor from Table 6472.3-1
$V$ = rated full load hoisting speed, ft/min
$W$ = weight of the rated load on the hook plus the weight of the block, lb

**6472.2 Bridge and Trolley** **(15)**

*(a)* The force required to drive the bridge or trolley consists of that necessary to overcome rolling friction, and that necessary to accelerate the crane. The rolling friction is proportional to the total weight of the crane and is assumed to be constant at all speeds. Unless otherwise specified, a friction factor per Table 6472.2-1 shall be used for antifriction bearing cranes. Mechanical efficiencies are included in these factors.

**Table 6472.2-1**
**Overall Friction Factors (Antifriction Bearings)**

| Wheel Diameter, in. | Friction, lb/ton |
|---|---|
| 8 | 22 |
| 10 | 18 |
| 12 | 15 |
| 15 | 15 |
| 18 | 15 |
| 21 | 12 |
| 24 | 12 |
| 27 | 12 |
| 30 | 10 |
| 36 | 10 |

**Table 6472.2-2 Suggested Acceleration Rates for AC or AV Travel Drives**

| AC or AV Drives Rated Speed [Note (3)] | | Acceleration Rate [Notes (1) and (2)] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Slow [Note (4)] | | Medium | | Fast | |
| ft/min | ft/sec | $a$, ft/sec$^2$ | $t$, sec | $a$, ft/sec$^2$ | $t$, sec | $a$, ft/sec$^2$ | $t$, sec |
| 30–60 | 0.5–1.0 | 0.15–0.30 | 3.3 | 0.2–0.4 | 2.5 | 0.25–0.5 | 2 |
| 120 | 2.0 | 0.4 | 5 | 0.6 | 3.33 | 0.8 | 2.5 |
| 180 | 3.0 | 0.5 | 6 | 0.75 | 4 | 1.0 | 3 |
| 240 | 4.0 | 0.6 | 6.7 | 0.8 | 5.0 | 1.0 | 4 |
| 300 | 5.0 | 0.7 | 7.14 | 0.9 | 5.55 | 1.1 | 4.5 |

NOTES:
(1) Since acceleration rates are for full-load conditions, lesser loads on the same drive will produce faster acceleration rates unless the drive has a regulator that provides controlled rate acceleration.
(2) Due to wheel slip considerations, it is suggested that the maximum acceleration rate not exceed the values in Table 6472.2-3 based on a wheel to rail adhesion of 20%. If the adhesion is less than 20% or if a multimotor drive without a line shaft is being used, the maximum rate should be reduced accordingly.
(3) 200 ft/min is considered the maximum for pendant operated cranes.
(4) Since fast acceleration may result in less precision for spotting and jogging, acceleration rates less than those shown in the slow column may be desirable where precise positioning is required.



**Table 6472.2-3**
**Suggested Maximum Acceleration Rates**

| Wheels Driven, % | Maximum $a$ |
|---|---|
| 50 | 2.4 ft/sec$^2$ |
| 33⅓ | 1.6 |
| 25 | 1.2 |
| 16⅔ | 0.8 |
| 12½ | 0.6 |

*(b)* Unless otherwise specified, the acceleration rate with rated load for either AC or adjustable voltage (AV) drives is to be selected from the slow values shown in Table 6472.2-2.

*(c)* The size of the bridge and trolley motor shall not be less than the computed from eq. (2):

$$hp = K_s K_a W_t V \quad (2)$$

where

$K_a$ = a factor that includes power for both overcoming friction and accelerating the crane or trolley. Based on certain assumptions, values of $K_a$ for either AC drives or adjustable voltage drives with constant motor field strength are given in Fig. 6472.2-1. The rate of acceleration is based on the total time to accelerate from zero speed up to rated speed. The factors assume the rotating inertia to be 10% of the equivalent load inertia (based on $W_t$), a mechanical efficiency of 95%, and an average motor torque equal to 150% of the motor rated torque when $K_s$ = 1.0. $K_a$ factors for constant potential DC series motor drives are to be in accordance with AISE TR No. 6, noting that the acceleration rates may exceed those shown in Table 6472.2-2 since they apply only up to the speed attained on the resistor, as explained in that standard. Due to wheel-slip considerations, it is suggested that the maximum acceleration rate not exceed the values in Table 6472.2-3, based on a wheel-to-rail adhesion of 20%.

$K_s$ = a service factor to provide an allowance for motor heating resulting from repetitive operations (Table 6472.3-1)

$V$ = specified speed, ft/min

$W_t$ = total weight of the crane or trolley plus rated load, ton

*(d)* After selecting an approximate motor by eq. (2), obtain data on the $Wk^2$ of the motor, brake wheel, couplings, and pinion. The sum of these values is the rotating $Wk_R^2$. Calculate the equivalent $Wk^2$ of the load by the following equation:

$$Wk_L^2 = 2{,}000 W_t (V/2\pi N_f)^2 \quad (3)$$

*(e)* If the motor is being selected for a duty class rather than a specified duty cycle, the motor rating should not be less than

$$hp = K_S \,[(W_t\, 2000V)/(33{,}000T_a)] \times [(f/2{,}000) + a/(32.2E) + a/(32.2) \times Wk_R^2/Wk_L^2] \quad (4)$$

where

$a$ = average acceleration rate, ft/sec$^2$

$E$ = mechanical efficiency, per unit

$f$ = friction factor, lb/ton

**Fig. 6472.2-1 $K_a$ Factors for AC and Adjustable Voltage DC Motors (Without Field Weakening)**

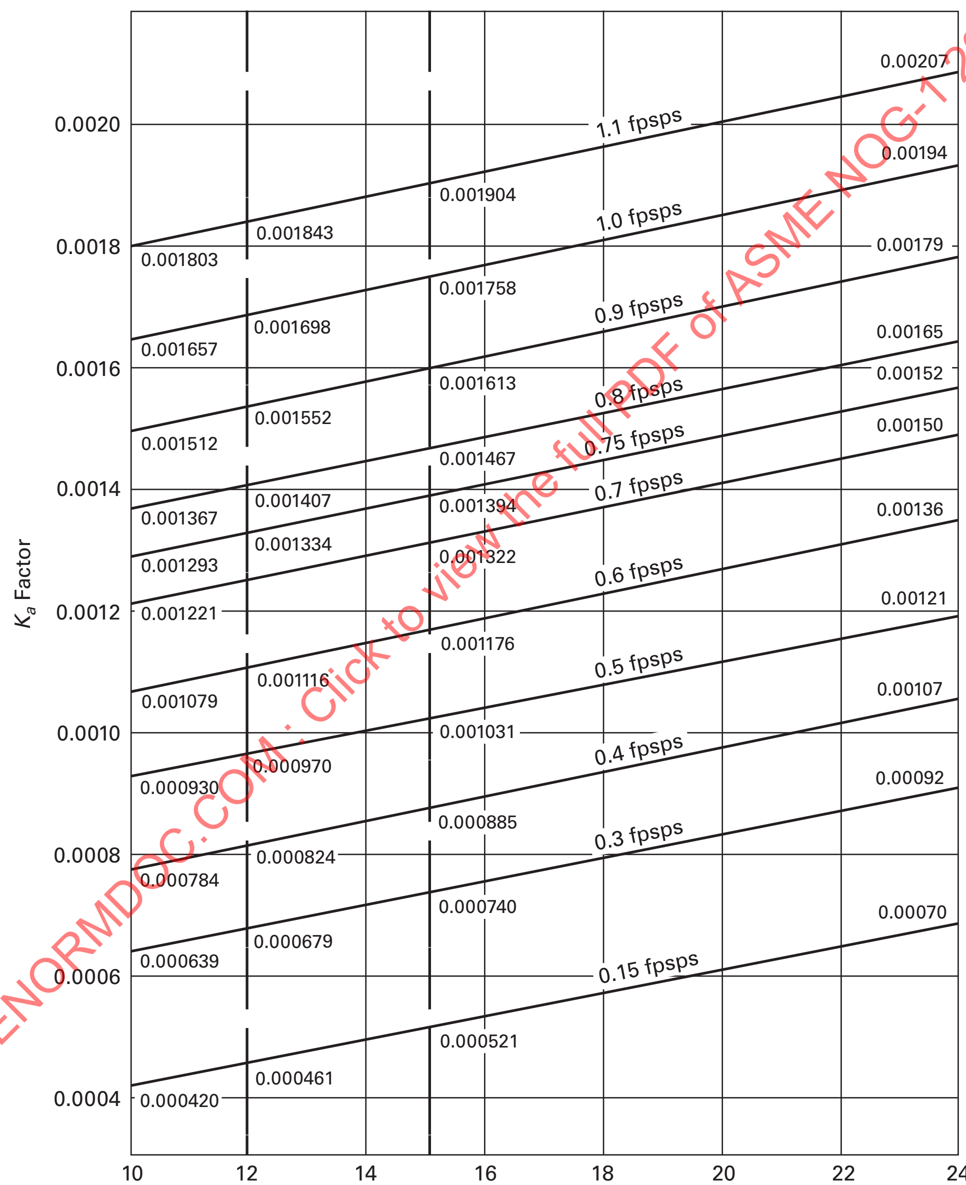
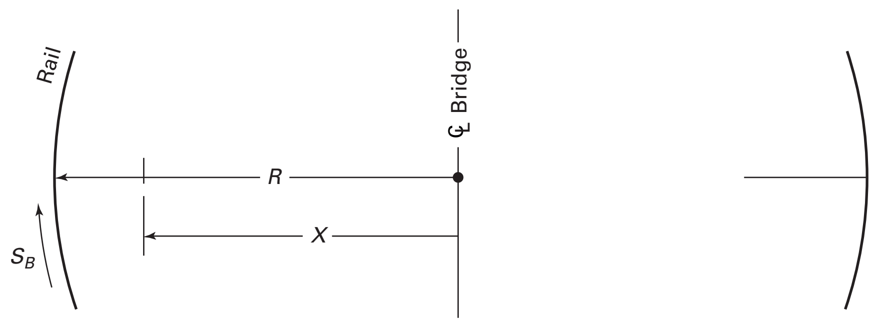


**Fig. 6472.2-2 Typical Polar Crane**




$T_a$ = average per unit motor torque provided during acceleration if $K_s = 1$

Using eq. (4) and $K_s = 1.0$, $E = 0.95$, $T_a = 1.5$, and $Wk_R^2/Wk_L^2 = 0.1$.

$$\text{rated } hp \geq 1.0\ [(W_t\ 2{,}000\ V)/(33{,}000 \times 1.5)] \times [(f/2{,}000) + a/(32.2 \times 0.95) + (a/32.2) \times 0.1]$$

NOTE: For constant potential DC series motor drives (or any drive where the free-running speed exceeds the motor rated speed at the applied voltage), multiply $V$ in eq. (4) by $N_R/N_t$, where $N_R$ is the motor rated speed at the applied voltage and $N_t$ is the free-running motor speed. If this procedure is used, a applies only up to $N_R$, and should be selected on that basis.

See para. B-6472.3 for sample bridge motor horsepower calculations.

(f) The speed ratio for bridge and trolley drives will be determined as shown in para. 6473, computing the free-running $hp$ from eq. (5)

$$hp = fW_tV/33{,}000 \tag{5}$$

where $f$ = rolling friction, lb/ton. For $f = 15$ lb/ton,

$$hp = 0.000455\ W_tV \tag{6}$$

(g) *Polar Cranes:* horsepower for bridge drives

$$hp_B = [(2/3)S_B \times W_B \times TE]/33{,}000 \tag{7}$$

$$hp_{TL} = [(X/R)S_B \times (W_T + W_L) \times TE]/33{,}000 \tag{8}$$

$$hp = hp_B + hp_{TL} \tag{9}$$

where

$hp$ = total horsepower of bridge motors
$hp_B$ = horsepower to drive bridge (less trolley and load)
$hp_{TL}$ = additional bridge motor horsepower to drive trolley and load
$R$ = radius of bridge (span/2) (see Fig. 6472.2-2)
$S_B$ = speed of bridge at wheel, ft/min (see Fig. 6472.2-2)
$TE$ = tractive effort, lb/ton
$W_B$ = weight of bridge, ton
$W_L$ = weight of load, ton
$W_T$ = weight of trolley, ton
$X$ = radius from bridge centerline to point of maximum hook approach (see Fig. 6472.2-2)

Use tractive effort constant from

$$TE = 22.5 + S_B/20 \tag{10}$$

This value of $TE$ gives approximately 1 ft/sec$^2$ acceleration. For running horsepower to select the drive speed ratio, use the actual rolling friction in lb/ton in place of $TE$ in the above equations.

### 6472.3 Service Factors

(a) As stated in para. 6472(a), the most severe requirements should be stated in the specifications whenever possible so the supplier can check the specific motor and control required.

(b) If the crane specifications do not indicate a specific duty but state the duty class for each motion, the $K_s$ values for eqs. (1), (2), and (4) are listed in Table 6472.3-1. There is no guarantee that these values will result in the optimum motor selection, but they do indicate relative ratings.

### 6472.4 Calculation of Motor Heating

(a) When definite operating requirements have been specified, the time, motor torque, and average motor speed can be calculated for each step of acceleration, running, and deceleration. The procedure for checking the thermal adequacy of the motor will vary, depending on the type of motor and motor enclosure. For totally enclosed series wound AISE TR No. 1 DC mill motors used for constant-potential DC control at 230 V, published curves may permit determining whether or not the allowable percent time-on exceeds the actual percent time-on. If the same type of motor is used at more than 230 V, the motor manufacturer shall be consulted to evaluate the effect of the increased core losses and friction and windage losses.

## Table 6472.3-1 Duty Classes

| Duty Class | Maximum Time On, % | Maximum [Note (1)] Cycles/hr | Time Rating [Note (2)], min: Hoist | Time Rating [Note (2)], min: T & B | $K_s$: DC AV. & CP: H | $K_s$: DC AV. & CP: T & B | $K_s$: AC — H [Note (3)]: Includes Resistance for Counter Torque and Slow Speed | $K_s$: AC — H [Note (3)]: Fixed Resistance | $K_s$: AC — T & B: Includes Resistance for Slow Speed and Plug | $K_s$: AC — T & B: Fixed Resistance [Note (4)] |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20 | 15 | 30 | 30 | 1.0 | 1.1 | 1.0 | 1.1 | 1.1 | 1.3 |
| 2 | 30 | 25 | 30 | 60 | 1.0 | 1.2 | 1.0 | 1.2 | 1.2 | 1.4 |
| 3 | 40 | 35 | 60 | 60 | 1.0 | 1.3 | 1.1 | 1.3 | 1.3 | 1.5 |
| 4 | 50 | 45 | 60 | 60 | 1.0 | 1.4 | 1.2 | 1.4 | 1.4 | 1.6 |

GENERAL NOTE: If mechanical considerations make it desirable to keep motor rated *hp* as low as possible, and if atmospheric conditions permit ventilated motors, use duty class 1 $K_s$ values for all duty classes above Class 1 to determine the motor 60-min, self-ventilated *hp* rating, then modify the motor by adding forced ventilation. This does not eliminate the necessity of checking the adequacy of an AC drive with a fixed secondary resistance if prolonged slow speed operation is required.

NOTES:

(1) Unless otherwise specified, a *cycle* is defined as follows:
For a hoist — raise rated load, lower rated load, hoist empty hook, lower empty hook — same distances.
For a trolley or bridge — carry rated load in one direction and return same distance with empty hook.

(2) For AC drives with static controls, the minimum time rating shall be 60 min.

(3) For a hoist, the specified full-load hoist speed must be obtained at not more than rated motor torque. To meet this requirement for an AC hoist that has some permanent secondary resistance during full-speed hoisting, and to include the selected service factor in a way that allows for the reduction in per unit slip when the service factor increases the motor rating, use the following equation instead of eq. (1) of Section 6000. The motor rating shall not be less than

$$hp = [K_s - 1 = 0.97/(1.0 \text{ per unit res.})]\ (WV/33{,}000\ E)$$

Obviously, if $K_s = 1$ and the slip rings are shorted on a motor with the 3% internal resistance that is assumed on these calculations,

$$hp = WV/33{,}000\ E$$

In other words, the minimum motor rating is the mechanical *hp* required for steady-state hoisting of rated load at rated speed.

(4) *Fixed resistance* means no secondary contactors to change secondary resistance, although there may be controlled reactance.

*(b)* On adjustable voltage DC drives, self- and forced-ventilated shunt motors can be checked by comparing the calculated rms current and average speed against curves of allowable rms current versus average rpm for the motors being checked. In totally enclosed motors, the losses (armature, field, core, brush, friction, windage, and stray load) shall be summarized to see if the total is below the dissipating capability of the selected motor operating over the repetitive cycle. Similarly, in AC motors, losses are divided into fixed and variable. As an approximation, the variable losses can be considered to be proportional to secondary current squared. Also, for a given value of secondary resistance, the secondary current can be calculated by

$$I = \sqrt{\text{torque} \times \text{slip}/\text{resistance}} \qquad (11)$$

all on a per unit basis. (If the calculated per unit $I$ is less than the corresponding per unit $T$, use the per unit $T$ value. Also, in order to take into consideration the primary copper losses at very low values of torque, the value of per unit $I$ shall not be less than 0.4.)

*(c)* The AC motor thermal evaluation could be performed as follows. Establish a duty cycle with the time and torque for each step calculated. Convert torque to per unit current using eq. (11) or the torque–current speed characteristics of the type of control to be used. Add the square of the per unit current × time (in seconds) × per unit variable losses to the operating time (in seconds) × per unit fixed losses. If that total is less than the sum of the seconds × the dissipation factors for each step in the cycle, the motor has adequate thermal capacity. The variable losses, fixed losses, and dissipation factors are to be obtained from the selected motor manufacturer, or the cycle summary shall be submitted to the manufacturer. See para. B-6472.4 for an example of AC motor heating calculation.

#### 6472.5 Duty in Excess of Class 4

*(a)* Above 50% time-on or more than 45 cycles per hour, the required duty cycle capability shall be stated by the specification writer, who should consider the possible advantages of self-ventilated, forced-ventilated, or air-over-frame motor construction, depending upon the atmospheric conditions at each installation. The acceptable type(s) shall be indicated in the specifications.

*(b)* If prolonged (over 30 sec) or repetitive operation at reduced speed is required, it shall be specified. Any reduced speed operations that fall below 5% speed for prolonged periods or that are repetitive shall not be evaluated by the procedures in para. 6472.4 without consulting the electrical manufacturer.

*(c)* Because variations in motors and controls can be appreciable, ratings selected by any duty cycle calculations shall be checked by the electrical manufacturer after an order has been placed.

**6473 Drive Speed Ratios.** Drive speed ratios ($SR$) shall be determined as follows: (15)

$$SR = (\pi D N_f)/(12RV) \qquad (12)$$

where
- $D$ = pitch diameter of drum for hoists or wheel diameter for traverse drives, in.
- $N_f$ = motor rpm corresponding to the free-running (i.e., steady state or developed) *hp* not including any accelerating hp, taking into consideration the voltage and control used as stated in (a) through (d) below
- $R$ = mechanical advantage of the rope system for hoists
  = 1 for traverse drives
- $V$ = specified speed, ft/min

*(a)* For 230 V DC series motors, the manufacturer's characteristic curves for 230 V shall be used. At a constant-potential voltage other than 230 V, obtain an equivalent 230 V *hp* by multiplying the free-running *hp* by 230 divided by the applied voltage. From the curves, use this equivalent *hp* to obtain the motor speed at 230 V. Calculate the approximate $N_f$ by multiplying the rpm so obtained by the applied voltage divided by 230.

*(b)* For AC wound rotor motors, the typical characteristic curves for wound rotor motors in Fig. 6473-1 shall be used, taking into consideration the total secondary resistance at full speed. The curves are based on motors providing 3% slip at rated torque with rings shorted and with rated voltage applied to the primary

$$hp_{pu} = T_{pu}\,(1 - T_{pu} \times \text{Res.}_{pu})/0.97 \qquad (13)$$

Per unit horsepower ($hp_{pu}$) for use of these curves

$$= \frac{\text{developed } hp \text{ (not incl. acceleration)}}{hp \text{ rating of motor}} \qquad (14)$$

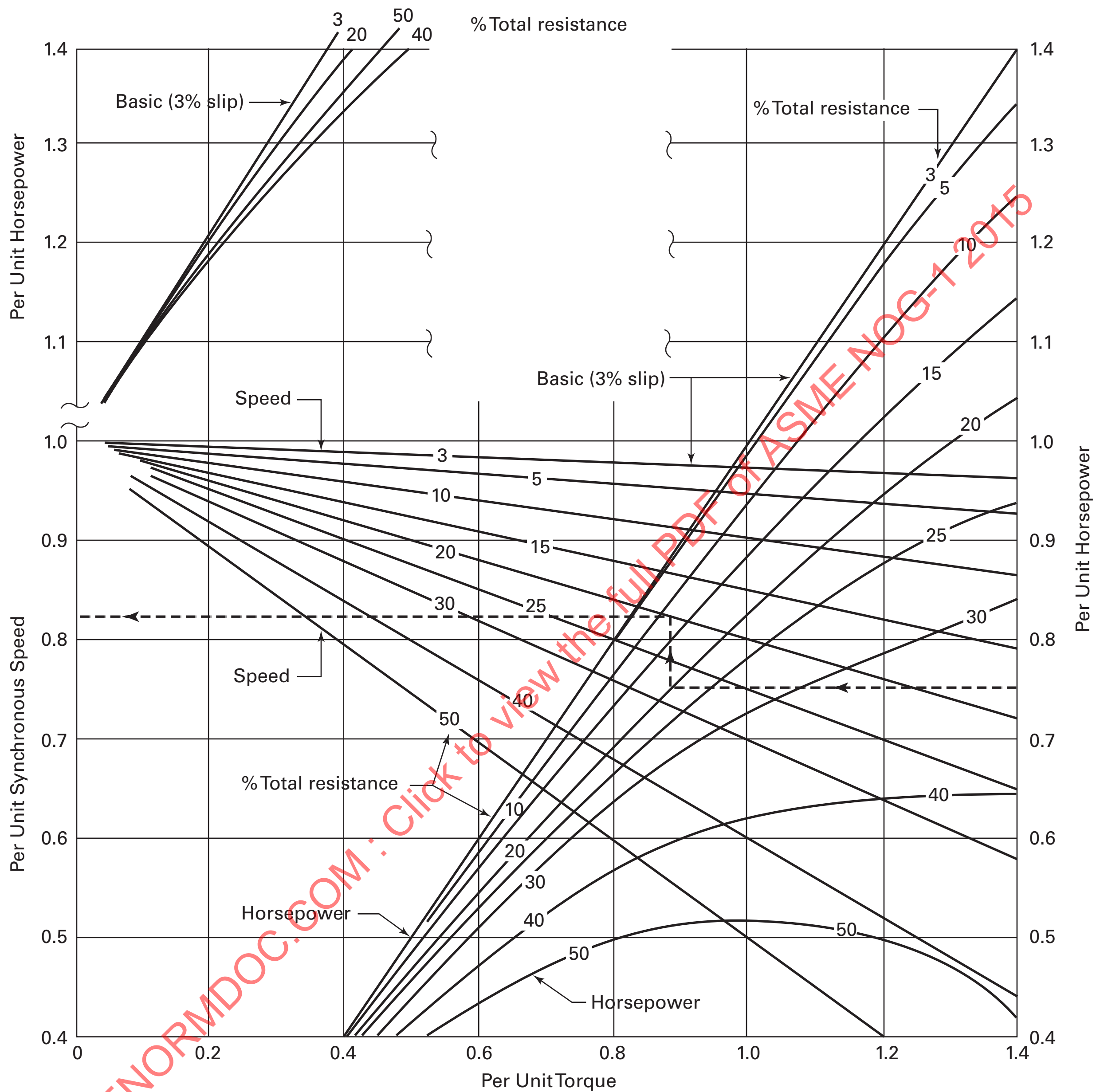
[The developed *hp* for a hoist is calculated by eq. (1) with $K_s = 1$, and for a bridge or trolley by eq. (9).]

At the calculated per unit horsepower, read per unit torque from appropriate *hp*-resistance curve and then read per unit synchronous speed at that torque on the speed curve for the same resistance. The dashed line is an example at 0.75 per unit horsepower and 20% total resistance, resulting in approximately 0.88 per unit torque and 0.82 per unit synchronous speed.

*(c)* For DC adjustable voltage shunt motors, obtain manufacturer's rated speed for armature voltage and field strength used.

*(d)* For AC squirrel cage motors, use the motor's specific characteristic curves, to be supplied by the motor manufacturer.

**Fig. 6473-1 Typical Characteristic Curves for AC Wound Rotor Motors (Examples for 0.75 per Unit Horsepower and 20% Total Resistance)**






## 6480 Conductor Systems (Types I, II, and III Cranes)

### 6481 General

*(a)* Conductor types and sizes shall be in accordance with NEC, taking into consideration the voltage drop limitations affecting the allowable voltage variations at the controller specified in para. 6411.2.

*(b)* If insulated, the insulation shall be rated for the radiation dose specified, if any.

*(c)* Each multiconductor control cable shall include spare conductors. The quantity of spares shall be approximately 10% of the total, but not less than two and not more than five being required.

*(d)* For repeated flexing service, the bending radius for the cable and the cable support system shall be not less than the minimum recommended for the cable by its manufacturer. Means shall be provided for supporting, extending, and retracting the cable to allow movement without exceeding the stress limit in the cable as stated by the cable manufacturer.

**6482 Conductor System Categories.** Conductor systems shall be considered in the following three general categories.

**6482.1 Runway Systems.** Conduct power from the building supply to the crane.

**6482.2 Bridge Systems.** Conduct power and control between the bridge and trolley portions of the crane.

**6482.3 Auxiliary Systems.** Such as pendant pushbutton, communication, remote control, and instrumentation cables.

### 6483 Conductor System Types

*(a)* When AC variable frequency controls are used, the runway and bridge conductor systems shall include a grounding conductor.

*(b)* The following three general types of conductor systems shall be considered to meet the needs of the three categories in para. 6482:

*(1) Contact Conductor.* These systems may consist of either a rigid bar or taut wire with a sliding or rolling collector. To ensure continuous contact on Type I, II, or III systems that use AC variable frequency drives or DC motor drives, there shall be at least two spring-loaded contact shoes per phase on main line systems in the primary circuit of AC motors and in any DC motor armature circuit that does not supply current to a series brake. Adequate expansion means shall be incorporated to allow for building expansions and contractions as specified. Where low-contact resistance is required for low-current or low-voltage pilot devices, such as tachometer generators, a combination of conductor and collector materials shall be suitable for that usage.

NOTE: While taut wire arrangements are present on many existing systems, the use of an uninsulated taut wire system is not recommended on new applications due to inherent safety issues.

*(2) Brush-Type Cable Reel.* These systems consist of a cable, which is payed out off of a reel, and uses a slip-ring and brush arrangement to maintain electrical contact. Where low-contact resistance is required for low-current or low-voltage pilot devices, such as tachometer generators, a combination of slip-ring and brush materials shall be suitable for that usage.

*(3) Flexible Continuous Conductor.* These systems consist of a continuous flexible cable, either flat or round, that is suspended in a festooned arrangement from a trolley and track system or in a cable carrier.

## 6500 ELECTRICAL EQUIPMENT TESTING REQUIREMENTS (TYPES I, II, AND III CRANES)

All electrical equipment shall be tested in accordance with Section 7000.

# Section 7000
# Inspection and Testing

## 7100 TESTS AND ACCEPTANCE CRITERIA

The following list identifies the specific tests and acceptance criteria for the inspections and tests specified by Tables 7210-1 and 7210-2:

*(a)* drop-weight test per ASTM E208 or Charpy impact test per ASTM A370. The owner or the owner's designated representative shall establish the acceptance criteria unless stated otherwise in this Standard.

*(b)* 100% radiographic test (RT) or ultrasonic test (UT) of butt welds in accordance with AWS D1.1. Acceptance criteria shall be in accordance with AWS D1.1.

*(c)* 10% magnetic particle test (MT) or dye penetrant test (PT) of the linear feet of each weld that exceeds 10 in. in length unless stated otherwise in this Standard. Technique and acceptance criteria shall be in accordance with AWS D1.1.

*(d)* ultrasonic (UT) volumetric testing

*(1) Plate Materials.* UT volumetric tests shall be performed in accordance with ASTM A435. Any area where one or more discontinuities produce a continuous loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. or one-half of the plate thickness, whichever is greater, is unacceptable.

*(2) Bar and Forged Material.* Ultrasonic volumetric tests shall be performed in accordance with the applicable sections of ASTM A388 after forging and heat treatment, but before any machining that would render the ultrasonic test results indeterminate. Additional requirements and acceptance criteria follow:

*(-a)* Solid shafts, bars, and forgings with parallel surfaces (i.e., providing an adequate back reflection to conduct the test) shall be ultrasonic tested using the straight-beam back-reflection technique. The test results shall be unacceptable if one or more reflectors produce indications accompanied by a complete loss of back reflection not associated or attributable to geometric configurations. Complete loss of back reflection is assumed when the back reflection falls below 5% of full calibration screen height.

NOTE: Conducting the test in accordance with subparagraph (b) below is also acceptable.

*(-b)* Solid shapes and forgings with nonparallel surfaces, as well as hooks, shall be ultrasonically tested using flat-bottomed hole reference standards and distance–amplitude correction curves. Discontinuity indications in excess of the response from a $\frac{1}{8}$-in. flat-bottomed hole at the estimated discontinuity depth shall be unacceptable.

*(-c)* Rings and hollow forgings shall be tested using the angle beam examination technique when a valid test using the back reflection technique through the axial direction cannot be performed. One or more reflectors that produce indications exceeding the amplitude reference line from the appropriate calibration notches shall be unacceptable.

*(e)* hooks for a Type I hoist. Hooks shall be proof load tested at 200% of the maximum critical load or in accordance with ASME B30.10 for the rated load, whichever test load is greater. Dimensional inspection of the hook (before and after proof load testing) and the testing procedure shall be in accordance with ASME B30.10. Acceptance criteria shall be in accordance with ASME B30.10 or shall be specified by the owner.

*(1)* Each load path of a dual load path hook shall be tested independently.

*(2)* Each load attaching point on the hook shall be tested separately. For example, the testing of a sister hook with a pinhole must include separate tests for the sister hook prongs and the pinhole.

*(3)* Testing of the load path through the sister hook prongs shall be performed in a manner that represents an applied load that has a 60 deg included angle, or at the included angle specified for hook design.

*(f)* wire rope breaking strength test. Breaking strength shall meet or exceed published breaking strength in accordance with Federal Specification RR-W-410 or wire rope manufacturer's published data. The sample used for the test shall be taken from the wire rope furnished.

*(g)* magnetic particle (MP) and liquid penetrant (LP) surface testing

*(1)* Magnetic particle testing for surface defects shall be performed in accordance with ASTM A275 and/or ASTM E709.

*(2)* Liquid penetrant testing shall be performed in accordance with ASTM E165.

*(3)* For both MP and LP testing, the acceptance criteria shall be as follows. The following relevant indications are unacceptable:

*(-a)* linear indications greater than $\frac{1}{16}$ in. long in material under $\frac{5}{8}$ in. thick, greater than $\frac{1}{8}$ in. long in

material from $\frac{5}{8}$ in. thick to under 2 in. thick, and greater than $\frac{3}{16}$ in. long in material 2 in. thick and over

*(-b)* rounded indications with any dimension greater than $\frac{1}{8}$ in. in material under $\frac{5}{8}$ in. thick, and greater than $\frac{3}{16}$ in. in material $\frac{5}{8}$ in. thick and over

*(-c)* in any thickness of material, four or more relevant indications separated by $\frac{1}{16}$ in. or less, edge-to-edge

*(-d)* in any thickness of material, ten or more relevant indications in any 6 $in.^2$ of surface with the major dimension of the area not to exceed 6 in., with the area taken in the most unfavorable orientation relative to the indications being evaluated

Relevant indications are those that result from mechanical discontinuities and have a major dimension greater than $\frac{1}{16}$ in. Indications may be explored to determine if they are the result of material discontinuities, material properties, or part geometry. Linear indications are those whose length is more than three times the width. Rounded indications are those that are circular or elliptical with the length less than three times the width.

## 7200 MANUFACTURING

Inspections and testing of Types I and II cranes shall conform to this Standard. Assurance of implementation of the requirements of this Subsection for Types I and II cranes shall be in accordance with Section 2000. The manufacturer's standard inspection and testing program shall apply to Type III cranes if not otherwise specified in this Standard or contract document.

### 7210 Receipt and In-Process Inspection and Testing Requirements

*(a)* Receipt inspection and testing shall be performed for those items listed in Table 7210-1 for Type I cranes and Table 7210-2 for Type II cranes. In-process inspection and testing shall be performed in accordance with Table 7210-1 for Type I cranes and Table 7210-2 for Type II cranes. (See para. 7100 for definitions of inspections and tests required by tables.)

*(b)* Documentation required by Table 7210-1 or Table 7210-2 shall be reviewed and accepted by the crane manufacturer prior to the assembly of any item listed in these tables.

*(c)* All structural welds shall be visually inspected over their entire lengths for any type crane. Acceptance criteria of welds and repair shall be in accordance with AWS D1.1.

### 7220 Electrical Documentation

On Type I cranes, reports of standard NEMA tests shall be furnished by the electrical equipment manufacturer for hoist and travel motors and brakes.

### 7230 Assembly Inspection Requirements

The crane shall be sufficiently assembled to ensure that parts are properly fitted. Permanent wiring, other than that normally done at field erection, shall be complete. Control panels and rigid conduit shall be installed. It is not required to reeve the drum and blocks, to attach the cab, or to erect on gantry legs.

Inspections of the work shall be performed by the crane manufacturer. The owner or the owner's designee may verify that crane components are being installed, assembled, or connected in compliance with the latest appropriate drawings, codes, standards, and procedures.

### 7240 Electrical Inspection Requirements (15)

Inspections shall be performed at the crane manufacturer's plant to verify the following:

*(a)* terminal connections for tightness

*(b)* panels and resistors are properly placed

*(c)* required fuses are installed

*(d)* panels, switches, resistors, and other parts and materials are in accordance with job drawings and are properly identified

*(e)* raceways are properly installed, and raceways to be removed for shipment are to be properly fitted for field installation

*(f)* no interferences involving electrical items exist when trolley moves through its full range

*(g)* electrical items do not protrude beyond the confines of the crane as established by the job drawings

*(h)* electrical items requiring routine maintenance are accessible

*(i)* no wiring is touching resistor heating parts

*(j)* portions of conductor systems that are designed to move in order to accommodate crane motion move freely

*(k)* ancillary electrical items are properly installed

*(l)* pendant cable strain relief(s) is supplied for pendant push-button, station-operated cranes

*(m)* overload relay current sensing elements are in accordance with job drawings

*(n)* motor connections are properly made

*(o)* contactors and electromechanical relays whose armatures are accessible operate freely by hand

*(p)* electrical enclosures are correct NEMA type and panel doors operate properly

*(q)* brushes are properly seated

*(r)* electrical holding brakes are adjusted to correct torque settings

*(s)* conductors are identified at each termination by being marked to correspond to the schematic diagram

### 7250 Shop No-Load Test

A shop no-load test shall be performed at the crane manufacturer's facility. Procedure(s) shall be prepared

## Table 7210-1 Required Inspections or Tests — Type I

| Items | Tests [Note (1)] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Material Test Reports | Certificate of Conformance From Item Manufacturer | RT or UT of Butt Welds [Para. 7100(b)] | MT or PT of Completed Welds [Para. 7100(c)] | UT — Base Material [Para. 7100(d)] | MT or PT of Surface [Para. 7100(g)] | Impact Test [Para. 7100(a)] | Proof Load Test (Including Dimensional) [Para. 7100(e)] | Breaking Strength Test [Para. 7100(f)] | Weld Filler Material C.C. Typical Value |
| Hook | X | . . . | . . . | . . . | X | X [Note (2)] | . . . | X | . . . | . . . |
| Hook nut or attachment device | X | . . . | . . . | . . . | X | X | . . . | X [Note (3)] | . . . | . . . |
| Trunnion or cross head | X | . . . | . . . | . . . | X | X | . . . | . . . | . . . | . . . |
| Load block load structures | X | . . . | . . . | . . . | . . . | . . . | X | . . . | . . . | . . . |
| Load block structural welds | . . . | . . . | . . . | X | . . . | . . . | . . . | . . . | . . . | X |
| Load block — sheave pin | X | . . . | . . . | . . . | X | X | . . . | . . . | . . . | . . . |
| Wire rope | . . . | X | . . . | . . . | . . . | . . . | . . . | . . . | X | . . . |
| Hoist drum | X | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| Hoist drum shell and hub welds | . . . | . . . | X | X | . . . | . . . | . . . | . . . | . . . | X |
| Hoist drum shafts | X | . . . | . . . | . . . | X | X | . . . | . . . | . . . | . . . |
| Upper block sheave pin | X | . . . | . . . | . . . | X | X | . . . | . . . | . . . | . . . |
| Upper block load structure | X | . . . | . . . | . . . | . . . | . . . | X | . . . | . . . | . . . |
| Upper block structural welds | . . . | . . . | . . . | X | . . . | . . . | . . . | . . . | . . . | X |
| Sheaves | . . . | X | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| Gears — hoist [Note (4)] | X | . . . | X | X | X | X | . . . | . . . | . . . | . . . |
| Pinions — hoist [Note (4)] | X | . . . | . . . | X | X | X | . . . | . . . | . . . | . . . |
| Shafts — hoist [Note (4)] | X | . . . | . . . | . . . | X | X | . . . | . . . | . . . | . . . |
| Trolley load girt structure | X | . . . | . . . | . . . | . . . | . . . | X | . . . | . . . | . . . |

(15)

## Table 7210-1 Required Inspections or Tests — Type I (Cont'd)

| Items | Material Test Reports | Certificate of Conformance From Item Manufacturer | RT or UT of Butt Welds [Para. 7100(b)] | MT or PT of Completed Welds [Para. 7100(c)] | UT — Base Material [Para. 7100(d)] | MT or PT of Surface [Para. 7100(g)] | Impact Test [Para. 7100(a)] | Proof Load Test (Including Dimensional) [Para. 7100(e)] | Breaking Strength Test [Para. 7100(f)] | Weld Filler Material C.C. Typical Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tests [Note (1)] | | | | | | | | | |
| Trolley girt — structural welds [Note (5)] | ... | ... | ... | X | ... | ... | ... | ... | ... | X |
| Girder top and bottom plates [Note (6)] | X | ... | ... | ... | ... | ... | X | ... | ... | ... |
| Girder top and bottom plate butt welds [Note (7)] | ... | ... | X | X | ... | ... | X | ... | ... | X |
| Fastener material for structural interconnection [Note (8)] | X | ... | ... | ... | ... | ... | X | ... | ... | ... |
| Girder web plates | X | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Girder web to top and bottom cover plate structural welds [Note (9)] | ... | ... | ... | X | ... | ... | ... | ... | ... | X |
| Girder internal stiffeners and diaphragm welds | ... | ... | ... | ... | ... | ... | ... | ... | ... | X |
| Girder to end truck attachment | X | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Girder to end truck — structural welds | ... | ... | ... | ... | ... | ... | ... | ... | ... | X |
| End tie — structure | X | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| End tie — structural welds | ... | ... | ... | ... | ... | ... | ... | ... | ... | X |
| Girder end trucks — structure | X | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Girder end trucks — structural welds | ... | ... | ... | ... | ... | ... | ... | ... | ... | X |
| Bridge and trolley — seismic restraints — structural | X | ... | ... | ... | ... | ... | ... | ... | ... | ... |

## Table 7210-1 Required Inspections or Tests — Type I (Cont'd)

| Items | Tests [Note (1)] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Material Test Reports | Certificate of Conformance From Item Manufacturer | RT or UT of Butt Welds [Para. 7100(b)] | MT or PT of Completed Welds [Para. 7100(c)] | UT — Base Material [Para. 7100(d)] | MT or PT of Surface [Para. 7100(g)] | Impact Test [Para. 7100(a)] | Proof Load Test (Including Dimensional) [Para. 7100(e)] | Breaking Strength Test [Para. 7100(f)] | Weld Filler Material C.C. Typical Value |
| Bridge and trolley — seismic restraints — structural welds | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | X |
| Weld test plates [Note (10)] | . . . | . . . | . . . | . . . | . . . | . . . | X | . . . | . . . | . . . |
| $^1/_8$ in. or greater welds [Note (11)] | . . . | . . . | . . . | X | . . . | . . . | . . . | . . . | . . . | . . . |
| Brake drum | . . . | X | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| Wire rope eyes and sockets [Note (12)] | . . . | X | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |

NOTES:
(1) For test identification details, see para. 7100.
(2) After proof load test.
(3) Load tested with hook.
(4) Surface hardness shall be verified when hardness values are specifically listed on manufacturer's design documents.
(5) Throat thickness $^1/_8$ in. and greater, 100% weld inspection.
(6) As required by para. 4212.
(7) As required by para. 4232.
(8) As required by para. 4222.
(9) Throat thickness $^1/_8$ in. and greater, 10% of length.
(10) See para. 4212.
(11) See para. 4251.4.
(12) Proof tested to 40% of the published breaking strength of the wire rope.

## Table 7210-2 Required Inspections or Tests — Type II

| Items | Tests [Note (1)] | | | | |
|---|---|---|---|---|---|
| | Material Test Reports | RT or UT of Butt Welds [Para. 7100(b)] | MT or PT of Completed Welds [Para. 7100(c)] | Impact Test [Para. 7100(a)] | Weld Filler Material C.C. Typical Value |
| Trolley load girt structure | X | . . . | . . . | X | . . . |
| Trolley girt frame — structural welds | . . . | . . . | X | . . . | X |
| Girder top and bottom plates [Note (2)] | X | . . . | . . . | X | . . . |
| Girder top and bottom plate butt welds [Note (3)] | . . . | X | X | X | X |
| Girder web plates | X | . . . | . . . | . . . | . . . |
| Girder web to top and bottom cover plate structural welds | . . . | . . . | X | . . . | X |
| Girder internal stiffeners and diaphragm welds | . . . | . . . | . . . | . . . | X |
| Girder to end truck attachment | X | . . . | . . . | . . . | . . . |
| Girder to end truck — structural welds | . . . | . . . | . . . | . . . | X |
| End tie — structure | X | . . . | . . . | . . . | . . . |
| End tie — structural welds | . . . | . . . | . . . | . . . | X |
| Girder end trucks — structure | X | . . . | . . . | . . . | . . . |
| Girder end trucks — structural welds | . . . | . . . | . . . | . . . | X |
| Bridge and trolley — seismic restraints — structural | X | . . . | . . . | . . . | . . . |
| Bridge and trolley — seismic restraints — structural welds | . . . | . . . | . . . | . . . | X |
| Weld test plates [Note (2)] | . . . | . . . | . . . | X | . . . |
| Welds $^3/_8$ in. or greater [Note (4)] | . . . | . . . | . . . | . . . | . . . |
| Fastener material for structural interconnnection [Note (5)] | X | . . . | . . . | X | . . . |

NOTES:
(1) Test identification detailed in para. 7100.
(2) As required by para. 4212.
(3) As required by para. 4232.
(4) See para. 4251.4.
(5) As required by para. 4222.

and used by the crane manufacturer in conducting the shop no-load test.

If subsequent manufacturing or associated activities affect the validity of this test or portions thereof, the appropriate portion of the test shall be repeated.

The crane manufacturer's personnel shall direct the test following the appropriate procedure(s).

Nonconformances found during the shop no-load test shall be treated as required by this Standard.

**7251 Prerequisites.** Prior to conducting the shop no-load test, the crane or applicable portions to be tested shall be assembled and wired subject to the following:

*(a)* The crane or its applicable portions need not be completely assembled, wired, or painted at time of testing if subsequent work will not influence or alter the results of the test.

*(b)* Temporary electrical connections for test purposes are acceptable for normally installed field wiring. Where conductor bar systems are used, only enough of the conductor bar lengths need be installed to set collector shoes and check trolley operations.

*(c)* When testing the operation of mechanical portions of the crane, the use of a temporary controller is acceptable.

*(d)* When testing electrical portions of the crane, the crane will be tested with the actual crane controls unless specifically excepted by the purchaser.

**7252 Mechanical Requirements.** As a minimum, the following mechanical functions shall be verified:

*(a)* traverse of the trolley frame with wheel assemblies and other trolley-to-bridge interface items for tracking and clearances on the bridge (powered operation is preferable if conditions permit).

*(b)* powered operation of bridge and trolley drive and hoist units.

*(c)* operation of accessories and components, including but not limited to such items as safety devices, emergency brakes, rail clamps, limit switches, overspeed switches, and load-limiting or load-detection systems, in accordance with design criteria.

*(d) Type I Cranes.* Type I hoists shall be two-blocked to demonstrate that the equipment is capable of withstanding two-blocking without damage. It is recommended that the two-blocking test be conducted at the highest hoisting speed produced by normal operations. However, the owner and supplier may agree on alternative speeds for this test or alternative methods for demonstrating the capability of the equipment to withstand two-blocking. A load hangup test or calculations shall be performed to confirm the capability of the equipment to withstand load hangup. This test and/or calculation is also recommended to be based on the highest normal hoisting speed; again, the owner and supplier may agree on alternative criteria.

**7253 Electrical Requirements.** A test of the crane electrical system shall be made to verify proper operation of the controls.

For radio-controlled cranes, the transmitter-receiver system need not be used for this test. An alternate means of operation of the receiver driven relay panel is acceptable.

### 7260 Preparation for Shipment Requirements

As a minimum, the preparation for shipment of Types I, II, and III cranes shall meet the requirements of Section 8000.

### 7270 Final Verification of Document Requirements

The owner or the owner's authorized representative shall verify the documentation that has been compiled by the manufacturer as required by para. A-7613.

## 7300 RECEIPT AND STORAGE REQUIREMENTS FOR STORAGE FACILITY AND/OR SITE

Assurance of implementation of the requirements of this subsection for Types I and II cranes shall be in accordance with Section 2000.

### 7310 Receiving Inspection

This subsection defines requirements for the receipt inspection of cranes to be fulfilled by the organization responsible for performing the handling, storage, and reshipment of the equipment. These requirements outline the criteria involved in the inspection to verify that the crane components have been received in accordance with contractual requirements. The receipt inspection verifies that the quality of the crane has not been reduced due to corrosion, contamination, deterioration, or physical damage resulting from its being shipped.

**7311 Requirements.** The following minimum requirements for receipt inspection apply to Types I, II, and III cranes.

**7311.1 Receiving Inspection Plan.** A Receiving Inspection Plan shall be prepared by the owner or owner's designated representative. The plan shall provide instructions for performing receiving inspection covering the following activities:

*(a)* documentation
*(b)* visual inspection
*(c)* marking and tagging
*(d)* testing
*(e)* preparation for storage

**7311.2 Receiving Inspection Plan Implementation.** Receiving inspection shall be initiated upon notification that the crane has arrived at the designated area. This inspection shall be carried out in accordance with the Receiving Inspection Plan.

**7312 Conformance to Documentation.** A review shall be made to ensure that a correlation exists between the item received and its supporting documentation. The review shall include a comparison of the release for shipment documents, equipment identification numbers, purchase order document numbers, and other item identification.

**7313 Visual Examination**

**7313.1 Preliminary Inspection.** A preliminary inspection shall be performed prior to unloading to identify damage that may have occurred. Observations for unusual conditions shall include

(a) *Fire.* Charred paper, wood, or paint, indicating exposure to fire or high temperature.

(b) *Excessive Exposure.* Weather-beaten, frayed, rusted, or stained containers indicating prolonged exposure during transit.

(c) *Environmental Damage.* Water or oil marks, damp conditions, dirty areas, or salt film (indicating exposure to seawater or winter road salt chemicals).

(d) *Tie Down Failure.* Shifted, broken, loose, or twisted shipping ties, and worn material under ties.

(e) *Rough Handling.* Splintered, torn, or crushed containers indicating improper handling; review of impact recording instrument readings, when required.

**7313.2 Item Inspection.** Item inspection shall be performed at the designated receiving area. Unless the package marking prohibits unpacking, the contents of all shipments shall be visually inspected to ascertain compliance with specified packing and shipping requirements. Items packaged in separate, moisture-proof, transparent bags shall be visually inspected without unpacking. Inspections shall be performed in a manner to avoid contamination of the item during inspection.

**7314 Marking and Tagging.** Items shall be inspected to verify that the markings and tags are affixed in accordance with Section 8000 and the purchase order documents. The Receiving Inspection Plan shall identify these marking and tagging requirements.

**7315 Testing.** In those cases where the purchase order documents and para. 7100 require testing during receiving inspection, the Receiving Inspection Plan shall delineate the test requirements and provide documentation instructions.

**7316 Preparation for Storage.** When the receiving inspection of an item has been completed, the item should be in satisfactory condition for storage. Assurance should be made that pipe caps or covers removed for receiving inspection are replaced, machined surfaces are protected, and crated items have been recrated in accordance with original purchase order requirements and para. 7260, governing preparation for shipment and storage.

### 7320 Handling Inspection

This subsection defines requirements for the handling inspection of cranes to be fulfilled by the organization responsible for performing the handling, storage, and reshipment of the equipment. These requirements outline the criteria involved in the inspection to verify that the crane components have been handled in an acceptable manner. The handling inspection verifies that the quality of the crane has not been reduced due to unacceptable methods and procedures for handling the crane.

**7321 Requirements.** An inspection program shall be established by the owner or the owner's designated representative for equipment and rigging in accordance with Section 8000.

### 7330 Storage Inspection

Prior to the commencement of storage activities, the owner or the owner's designated representative shall establish and maintain a storage inspection program consistent with the requirements of this Standard. The program shall specify the inspection surveillance intervals for these requirements.

**7331 Requirements.** Inspections and examinations shall be performed on a planned and systematic basis consistent with the requirements of Types I, II, and III cranes to verify that the integrity of the stored item and its protective cover, as provided for in para. 7260, are being maintained. Verification during the inspection activity shall be in accordance with Section 8000.

### 7340 Preparation for Reshipment

This subsection defines the requirements for preparation for reshipment of cranes to be fulfilled by the owner or the owner's authorized representative.

**7341 Requirements.** The following minimum requirements for reshipment apply to Types I, II, and III cranes. Measures shall be established and documented to ensure that the equipment has been maintained and preserved in accordance with established instructions, procedures, or drawings to prevent damage, deterioration, and loss as per paras. 7320 and 7330.

Prior to reshipment, the requirements of para. 7260 shall be verified or reestablished. The owner may waive specific requirements if waiving them is not adverse to quality, and provided the minimum requirements of para. 7310 are met.

The documentation generated as requirements of paras. 7310 through 7340 shall be completed prior to reshipment and retained as specified in para. A-7620.

## 7400 SITE

Assurance of implementation of the requirements of this section for Types I and II cranes shall be in accordance with Section 2000.

## 7410 Installation

### 7411 Preinstallation Verification

**7411.1 General.** Prior to the actual installation of Types I, II, and III cranes, there are certain preliminary inspections, checks, and similar activities that shall be completed to verify that the crane and the installation area conform to specified requirements, and that the necessary resources are available to assure that the quality of the crane will be maintained as the installation proceeds.

The quality requirements and quality assurance actions that are necessary during installation shall be planned and reviewed so that they are understood by the responsible individuals.

**7411.2 Identification (for Type I Cranes).** Checks shall be made to verify that the identity of received equipment has been maintained and is in accordance with the latest approved-for-construction drawings, equipment lists, specifications, and established procedures. If these checks disclose apparent loss of identification, the identity shall be reaffirmed prior to release for installation. Checks shall be made to verify that a control system for maintaining identification of items throughout installation has been established. Provisions shall be made for an alternative system for equipment identification to drawings, specification, or records when identification or markings must be destroyed, hidden, or removed from an item.

**7411.3 Processes and Procedures (Types I and II Cranes).** Consistent with the construction activities schedule, inspections or checks shall be performed to verify that procedures are ready when needed for use in the installation of the crane components. These inspections or checks shall include the verification of the following items:

*(a)* Approved procedures, drawings, manuals, or other work instructions are provided to the installer at the construction site.

*(b)* Special instructions and checklists as required are available at the installation area or attached to the item.

*(c)* Approved procedures and instructions for special processes such as coating, welding, and nondestructive examination are available at the site.

*(d)* Where applicable, personnel, procedures, and instructions shall have been qualified through the preparation of workmanship standards, samples, or mockups that simulate actual job conditions.

*(e)* Installation preparations have been completed, including such tasks as removal of packaging, conditioning, cleaning, and preliminary positioning.

*(f)* Jigs, fixtures, and equipment for special processes, if required, are available at the site and conform to specified requirements.

*(g)* Equipment for handling and placement of items is available at the site and is adequate to perform the work in accordance with specified requirements.

*(h)* Warnings and safety notices, appropriate to the activity, are posted.

**7411.4 Physical Condition and Record Review (Types I, II, and III Cranes).** Inspections or checks, as appropriate, shall be performed to verify that the crane items are in accordance with the specified requirements and that quality has been maintained. These inspections or checks shall include the following verifications:

*(a)* Protective measures and physical integrity during storage have been maintained in conformance with paras. 7330 and 7430, and Section 8000.

*(b)* Nonconformances have been satisfactorily disposed of or controlled.

*(c)* Items have been cleaned in accordance with specified requirements.

**7411.5 Site Conditions (Types I, II, and III Cranes).** Inspections or checks, as appropriate, shall be performed to verify that conditions of the installation area conform to specified requirements and precautions have been taken to prevent conditions that will adversely affect the quality of the item during installation. These inspection checks shall verify the following:

*(a)* Protection from adjacent construction activities is being provided, including implementation of appropriate exclusion and area cleanness requirements.

*(b)* Protection from inclement weather and other ambient conditions adverse to quality is being provided.

*(c)* Materials that may be deleterious to the crane items being installed are controlled.

*(d)* Installation of the crane will not adversely affect the subsequent installation of other equipment, and repair or rework on any nonconforming items can be performed satisfactorily.

*(e)* Permanent crane runway (or approved temporary) supports and mountings that will properly interface with the crane have been installed.

*(f)* Servicing or maintenance activity related to installation has been performed.

**7412 Control During Installation.** For Types I and II cranes, checking, inspection, examination, or testing activities shall be performed during the installation of crane components to ensure that the crane is being assembled in accordance with prescribed procedures. These activities shall be performed in a systematic manner to ensure surveillance throughout the installation process. A procedure shall be provided for the coordination and sequencing of these activities at established inspection points in successive stages of installation.

A method shall be implemented to ensure that engineering and design changes are documented and controlled during installation.

**7413 Process and Procedure Control.** For Types I and II cranes, checks shall be made to verify that a system of controls has been established and is being maintained at the construction site to assure the following:

*(a)* The applicable revisions of approved procedures, drawings, and instructions are being followed.

*(b)* Qualified and approved processes, materials, tools, and other equipment are being used by qualified personnel.

*(c)* The status of installation, inspections, examinations, or tests is clearly indicated or identified in inspection records.

*(d)* The installation, inspection, and testing sequence are being maintained.

*(e)* Identification, appropriate segregation, and disposition of nonconforming items are being controlled.

*(f)* Inspection and test reports are current, accurate, and complete.

**7414 Examination.** Nondestructive examinations, when required, shall be performed in accordance with para. 7100.

**7415 Inspection (Types I, II, and III Cranes).** Inspections of the work areas and the work in progress shall be performed to verify that crane components are being located, installed, assembled, or connected in compliance with the latest approved-for-construction drawings, manufacturer's instructions, codes, installation instructions, and procedures. Inspections performed shall include, as appropriate, the following:

*(a)* identification
*(b)* location and orientation of components
*(c)* leveling and alignment
*(d)* clearances and tolerances
*(e)* tightness of connections and fasteners
*(f)* fluid levels and pressures
*(g)* cleanness
*(h)* welding operations including materials and process controls
*(i)* adequacy of housekeeping, barriers, and protective equipment to ensure that items will not be damaged or contaminated as a result of adjacent construction activities

**7416 Assembled Inspection (Types I, II, and III Cranes).** Checks shall be performed to verify that all components have been correctly installed. If construction or associated activities affect the results of these checks, the checks shall be repeated if necessary to assure that the quality has not been adversely affected.

Checkout procedures to verify correctness of installation and ability to function shall include the following mechanical elements:

*(a)* proper positioning of mating parts, such as couplings
*(b)* completion of proper greasing or lubrication
*(c)* priming, venting, and filling of casings, reservoirs, etc.
*(d)* proper installation of seismic anchors and restraints
*(e)* reeving to conform to manufacturer's instructions
*(f)* recording camber of girders with trolley(s) at midpoint of span
*(g)* control of special bolting method
*(h)* inspection of electrical connections for good contact and conformance with wiring diagram
*(i)* inspection of bridge conductor-collector system for proper alignment

## 7420 Preoperational Testing and Inspection

This subsection defines requirements for preop testing and inspection to ensure that the equipment will perform as required for handling of items during construction. A preop testing and inspection program shall be established to demonstrate that the crane will perform satisfactorily in service. The preop testing shall be performed in accordance with written test procedures which incorporate the requirements and acceptance criteria contained in applicable documents, which include applicable manufacturer recommendations. The owner or the owner's designated representatives shall conduct and be responsible for the preop tests called for in these procedures, shall furnish all facilities necessary for the performance of such tests, and shall ensure that proper communications are established for control of testing.

Preop testing and inspection requirements discussed in this subsection shall be applicable to Types I, II, and III cranes; these testing requirements shall be completed after the equipment has been installed and prior to construction-operational use of the crane.

**7421 No-Load Test.** A no-load test will be performed on cranes, after the power supply has been verified to be in conformance with the crane specifications, to verify the following:

*(a)* motor rotation is correct
*(b)* lubrication and cooling systems are in service
*(c)* limit switches, interlocks, and stops are properly adjusted and set
*(d)* instrumentation is calibrated and in service as required
*(e)* controls are adjusted properly for all drives for hoist, trolley, and bridge through the speed ranges
*(f)* for Type I hoists: components, systems, and features having single-failure-proof functions related to retaining the load in event of failure in the primary load path are functioning correctly, and are properly adjusted and calibrated

**7421.1 Additional Requirements.** At the same time the no-load testing is being performed, the following information shall be recorded or observed:

*(a)* *Electrical for (Full-Speed Conditions)*

*(1)* motor volts

(2) motor amps
(3) motor rpm
(b) *Mechanical*
(1) noise level
(2) oil leaks
(3) excessive vibration
(4) complete check of crane to certified clearance drawing
(5) gear alignment and engagement
(c) *Structural*
(1) overall clearances
(2) trolley end approaches

**7422 Full-Load Test.** The crane shall be statically loaded at mid-span to a maximum of 100% of hoist manufacturer's rating, and the deflection of the bridge at its center shall be measured and recorded. With this load, the crane shall be operated through all drives for hoist, trolley, and bridge, and through all speed ranges to demonstrate speed controls and proper function of limit switches, locking, and safety devices. For Type I cranes, the manual critical load lowering device(s) shall be tested. For Type I cranes, each holding brake shall be tested individually to verify that it will stop and hold the test load. The manual means of moving the trolley and bridge shall be tested.

(15) **7423 Rated Load Test.** After the no-load test and full-load tests are completed, and prior to use of the crane to handle loads, the crane shall be rated load tested.

(a) The crane shall receive a rated load test of 125% (+5%, −0%) of the manufacturer's rated load.

(b) The rated load test shall consist of the following operations as a minimum requirement:

(1) Lift the test load a distance to ensure that the load is supported by the crane and held by the hoist brakes.

(2) Transport the test load by means of the trolley from one end of the crane bridge to the other. The trolley shall approach the limits of travel as close as is practical in the event use area restrictions are imposed.

(3) Transport the test load by means of the bridge for the full length of the runway in one direction with the trolley as close to the extreme right-hand end of the crane as is practical in the event use-area restrictions are imposed, and in the other direction with the trolley as close to the extreme left end of the crane as is practical in the event use-area restrictions are imposed.

(4) Lower the test load, stop, and hold the load with the brakes.

(5) Verify that the nameplate reflects load rating per (a) above.

**7424 Certification.** A written report confirming that the crane has successfully passed the rated load test load rating of the crane shall be furnished. This report shall be signed by representatives of all parties participating in the test.

### 7430 Cranes Used for Construction (Types I, II, and III Cranes)

Temporary use of cranes to which this Standard applies that are to become part of the completed project may be desirable. However, authorization for such usage shall be as provided for in the contract or by written approval from the responsible organization. Such use shall not subject the crane to conditions for which it was not designed. The temporary use authorization shall include

(a) conditions of use
(b) maintenance requirements
(c) inspections and test as required to maintain operability and quality during periods of temporary use of the crane
(d) requirements for maintaining operating and maintenance logs

When temporary use is completed, conditions of temporary use shall be evaluated to verify that the crane continues to satisfy the specified requirements for its permanent intended use.

## 7500 QUALIFICATION FOR PERMANENT PLANT SERVICE

Assurance of implementation of the requirements of this subsection for Types I and II cranes shall be in accordance with Section 2000.

### 7510 Construction Use Record Review

**7511 Requirements.** Measures shall be established and implemented for the reviewing of construction use records for Types I, II, and III cranes. As a minimum, the following construction use records shall be reviewed by qualified personnel:

(a) maintenance log
(b) operating log

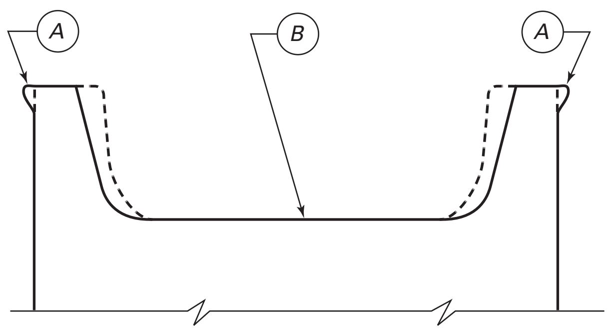
**7512 Documentation.** Documentation to substantiate that construction use record review has been completed as required by para. 7511 shall be validated. This documentation shall be maintained in accordance with para. A-7630. These records shall be considered valid only if stamped, initialed, signed, or otherwise authenticated and dated by authorized personnel.

### 7520 Inspection Prior to Performance Testing

This subsection is intended to outline the inspection requirements necessary to qualify Types I, II, and III cranes for permanent plant service after construction use.

**7521 Requirements.** Systems and procedures shall be established by the owner or the owner's designee to

### Fig. 7521.2-1 Inspection for Wheel Wear




GENERAL NOTES:
(a) Wheels should be replaced when wheel flanges become thin and visible curling begins to appear at *A*.
(b) When crane or trolley tends to run out of square as evidenced by persistent wheel flanging, check tread diameter *B* of all mechanically interconnected wheels. If the circumferences are mismatched by more than $^{1}/_{16}$ in. at the center of the tread, wheels should be replaced.

ensure that the inspection requirements as delineated within this Section are accomplished and documented by qualified personnel. These requirements are minimums and may be added to after review of construction use records if applicable. Discrepancies shall be corrected and reinspected in accordance with this Standard.

#### 7521.1 General

*(a)* Prior to making mechanical and electrical inspections, the construction use logs shall be reviewed as required by para. 7510 of this Standard. Special attention shall be given to inspection of problem areas as noted in construction use logs.

*(b)* Cranes shall be checked for cleanness. Dirt and foreign material shall be removed prior to inspection.

#### 7521.2 Mechanical Inspection

*(a)* Inspection covers shall be cleaned and opened, and exposed components shall be inspected for physical damage.

*(b)* Oil in reservoir shall be visually inspected for cleanness, filling to proper level, and foreign material.

*(c)* Gears shall be rotated so that all teeth on all gears can be inspected for pitting, featheredges at the tips of teeth, and misalignment.

*(d)* Bolts shall be inspected for tightness.

*(e)* Couplings shall be inspected for tight bolts, elongation of bolt holes, and tightness of keys in keyways.

*(f)* Bridge and trolley drive and idler wheels shall be inspected for excessive flanging and flat spots. See Fig. 7521.2-1.

*(g)* External welds listed in Tables 7210-1 and 7210-2 shall be visually examined.

*(h)* All structural members shall be visually inspected by a qualified person for damage resulting from abuse or neglect.

*(i)* Verify camber and compare with recording made per para. 7416(f).

*(j)* Sheaves shall be inspected for wear and defects that could damage wire rope.

*(k)* Bumpers and stops shall be verified as intact and operable.

*(l)* Bearing housings shall be inspected for integrity, lubrication, and cleanness.

*(m)* Trolley rail clips and trolley rails shall be inspected for tightness, excessive wear, and alignment.

*(n)* Cab glass shall be inspected and replaced as necessary.

*(o)* Wire rope shall be inspected for broken wire, strands, twists, kinks, or signs of wear.

*(p)* Capacity signs shall be inspected for visibility from the operating floor.

*(q)* Hoist drums shall be inspected for wear and defects that could damage wire rope. If groove root diameter is worn in excess of one-fourth the rope diameter, drum shall be replaced.

*(r)* Hook shall be inspected in accordance with ASME B30.10. Hook dimensions shall be validated. A record of this validation shall be maintained in accordance with para. A-7630.

*(s)* Top nut on hook shank shall be verified to be secure and not turned on shank.

*(t)* Hook shall be inspected to see that it swivels easily and that thrust bearing is lubricated and in good condition.

*(u)* All hydraulic and pneumatic systems shall be inspected for leaks and damage.

**7521.3 Electrical Inspection (Visual) While Crane Is Immobile.** A qualified electrician shall be assigned to the electrical inspection. All electrical power to the crane is to be locked out and under the control of the inspector. (15)

*(a) Motors*

*(1)* Inspect all brushes for wear, even contact, and damage.

*(2)* Inspect springs for tension on brushes.

*(3)* Inspect slip rings for pitting and wear.

*(4)* Inspect wires and terminals for tightness.

*(5)* Inspect insulation on wires for cracks or brittleness.

*(6)* Verify that motor bearings are properly lubricated.

*(b) Other Electrical Components*

*(1)* Inspect connections for tightness.

*(2)* Inspect collector system for physical damage.

*(3)* Inspect insulators for cracks.

*(4)* Inspect contactor and relay contacts for wear, pitting, and burning (does not apply to sealed relay contacts).

*(5)* Verify that timers are functioning and properly set.

*(6)* Verify that all panel doors shut properly and door seals are intact.

*(7)* Inspect resistors for burned-out sections, breaks, or cracks in insulation.

*(8)* Inspect disconnect switches and overload devices.

*(9)* Inspect master switch(es) or pendant push-button station contacts for operation, tight connections, and wear or pitting (unless contacts are sealed).

*(10)* Inspect limit switches for operation, tight connections, and wear or pitting (unless contacts are sealed).

*(11)* Inspect electrical enclosures for cleanness.

*(12)* Verify pendant cable strain relief(s) is installed and functioning properly.

*(c)* Verify the integrity of electrical enclosures and conduit systems.

### 7530 Testing Requirements

The crane shall be tested in accordance with para. 7420.

### 7540 Modification and Changes

Modifications and changes in design shall be reviewed and approved by the owner or owner's designated representative. These changes in design shall be inspected and tested in accordance with this Standard.

### 7550 Recertification

**7551 Crane Not Used for Construction.** When the crane has not been used for construction and has been certified in accordance with para. 7420, it requires no recertification.

**7552 Crane Used for Construction.** When used for construction, the crane, including any components installed subsequent to construction usage, shall be recertified by a qualified individual in accordance with paras. 7420 and 7500. The record of successful completion of these tests shall be signed by all participating parties.

## 7600 DOCUMENTATION

The owner shall define, in its purchase documents, the requirements for the collection, storage, and maintenance of documentation applicable to procurement, design, manufacture, shipment, receipt, storage, installation, and startup of cranes covered by this Standard. Guidance for determining documentation requirements to be specified in the owner's purchase documents is provided in Nonmandatory Appendix A.

As a minimum, design and manufacturing documentation to be specified in the owner's purchase documents for all cranes shall include assembly and outline drawings; electrical schematics and wiring diagrams; acceptance test plans and procedures; software test plans for controls; operating instructions; maintenance instructions; and software programs. Installation documentation to be specified in the owner's purchase documents for all cranes shall include records of high strength bolt torquing, data sheets or logs on equipment installation inspection and alignment, lubrication records, documentation of testing performed after installation and prior to acceptance, results of end-to-end electrical tests, final system adjustment data, acceptance test procedures and results, and load tests. Additionally, for Types I and II cranes, design calculations and load summary reports shall be included.

The owner's quality assurance program shall define which of these quality assurance documents are permanent records. Assurance of the implementation of the quality assurance documentation requirements contained in the owner's purchase documents for Types I and II cranes shall be in accordance with Section 2000.

# Section 8000
# Packaging, Shipping, Receiving, Storage, and Handling

## 8100 GENERAL

The packaging, shipping, receiving, storage, and handling of Types I and II nuclear facility cranes shall be governed by the applicable sections of ASME NQA-1, Part II, Subpart 2.2 and the modifications of this Section, as listed in Table 8100-1, or shall meet the quality assurance requirements specified by the owner. Type III cranes shall meet requirements of procurement documents.

Receiving, storage, and handling functions, per Table 8100-1, are normally applicable to organizations other than crane manufacturers who perform under the requirements of this Standard.



**Table 8100-1 Applicable Requirements of ASME NQA-1, Part II, Subpart 2.2, With Modifications of 8000**

| Subject | Applicable Section of ASME NQA-1, Part II, Subpart 2.2, and Modifications |
|---|---|
| General | 1- and 1.1 |
| General requirements | 2-, 2.1 [Note (1)], 2.2 [Note (1)], 2.2.3 [Note (2)], and 2.2.4 [Note (3)] |
| Packaging | 3.1, 3.2, 3.2.2 [Notes (4) and (5)], 3.2.3 [Notes (4) and (5)], 3.2.4 [Note (6)], 3.3, 3.4, 3.4.1, 3.4.2, 3.5, and 3.5.1 |
| Shipping | 4.1, 4.2, 4.2.1, 4.2.2, 4.2.3 [Note (7)], 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5, 4.3.6, 4.3.7, 4.4, 4.5.1, 4.5.2, 4.5.3, 4.5.4, and 4.5.5 |
| Receiving | [Note (8)] |
| Storage | 6.1, 6.1.1, 6.1.2 [Note (9)], 6.2, 6.2.1, 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.3, 6.3.1, 6.3.2, 6.3.3, 6.3.4, 6.3.5, 6.4, 6.4.1 [Note (10)], 6.4.2, 6.4.3, and 6.5 |
| Handling | 7.1 |

GENERAL NOTE: Requirements of ASME NQA-1, Part II, Subpart 2.2 not referenced are not invoked by this Standard.

NOTES:

(1) Concerning the referenced Introduction of this Part (Part II), omit Paragraph 2, Part 4.1.

(2) This classification includes additionally totally enclosed electrical components and omits Category (R).

(3) This classification includes:
- *(a)* crane bridge girder, end trucks, and separators
- *(b)* trolley trucks and separators
- *(c)* walks and railings

(4) Degree of integrity of enclosures for electrical components may satisfy Item (e) requirements of 3.2.1.

(5) The integrity of enclosures for components specified in 2.2.2 and Note (4) above may satisfy Item (d) requirements of 3.2.1, or Item (b) requirements of 3.2.3.

(6) Items (a) through (d) only.

(7) Item (c) is not applicable.

(8) Receiving procedures and inspections shall be in accordance with para. 7310.

(9) When Level D storage is selected, the duration of storage should be considered.

(10) Inspection and examination of items in storage shall be in accordance with para. 7330.

# Section 9000 Planned Engineered Lifts

## 9100 GENERAL

*(a)* Planned engineered lifts (PELs), as defined in ASME B30.2, are lifts in excess of the rated load, which are required from time to time on a limited basis for specific purposes, such as new construction or major repairs.

*(b)* An example of when planned engineered lifts may be required for a nuclear power plant would be the use of an existing reactor building crane for replacing steam generators, where the weight of the steam generator or steam generator sections exceeds the rating of the crane.

*(c)* Planned engineered lifts for nuclear facilities shall be in accordance with ASME B30.2, except as follows:

*(1)* Capacity limitations shall be in accordance with para. 9200.

*(2)* Lift frequency limitations shall be in accordance with para. 9300.

*(3)* Inspection frequency shall be in accordance with para. 9400.

*(d)* Additionally, the following shall apply to planned engineered lifts that are to be made at nuclear facilities:

*(1)* PELs may apply to the bridge or gantry only in accordance with para. 9500, or to the hoist and trolley only in accordance with para. 9600.

*(2)* Temporary interlocks or stops may be required in accordance with para. 9700.

*(3)* Load testing may be required in accordance with para. 9800.

*(4)* Crane wheel loads shall meet the requirements of para. 9900.

## 9200 CAPACITY LIMITATIONS

*(a)* Planned engineered lifts shall be permitted for powered cranes having a load rating of 5 tons and above, provided the PEL capacity is limited as follows:

*(1)* either the PEL capacity shall not exceed 125% of the crane's rating as established by this Standard or by the original CMAA 70 crane standard to which the crane was designed or qualified, or

*(2)* for PEL capacities over 125% of the crane's rating, the PEL shall not exceed that load, verified by calculation, which produces stresses under the operating loading conditions, using the PEL load in lieu of the original rated load, where the allowable stresses are increased to the "Severe Environmental" levels

*(-a)* Calculations to determine the maximum PEL load shall include a vertical impact factor based on 0.5% of the hoisting speed in feet per minute, but not less than 15%.

*(-b)* Calculations shall be performed by the crane manufacturer or by a qualified person.

*(b)* Seismic shall be included if specified by the owner. "Extreme Environmental" loading conditions shall be used for the seismic load case.

## 9300 LIFT FREQUENCY LIMITATIONS

*(a)* Planned engineered lifts shall be permitted, provided the frequency for making the PELs is limited to a maximum of 20 lift occurrences on the crane within any consecutive 10-yr period.

*(b)* A lift occurrence for making PELs shall be the handling of a single component or single component section.

*(c)* The raising and lowering of a single component or component section several times, for final position, load balancing, or for fit up, shall be considered a single lift occurrence.

*(d)* The removal of a component and then the later relocation or replacement of the same component shall be considered two separate lift occurrences.

## 9400 INSPECTION FREQUENCY

The ASME B30.2 inspections shall be performed before and after each PEL, except that for PELs that are performed in sequence, such as lifts made during a steam generator replacement, the ASME B30.2 inspections shall be performed before and after the first PEL, before and after the maximum PEL, and after the last PEL.

## 9500 PLANNED ENGINEERED LIFTS FOR BRIDGE OR GANTRY ONLY

*(a)* If the application requires only the existing bridge or gantry to make lifts in excess of the rated load, then only the components and structures associated with the bridge or gantry need to be qualified for making PELs.

*(b)* In the case of an existing bridge or gantry that is to be used in conjunction with a temporary lifting device (TLD), mounted on top of the bridge structure and having a rating equal to or exceeding the load of the planned

engineered lift, only the bridge or gantry is required to be qualified for making the PELs.

## 9600 PLANNED ENGINEERED LIFTS FOR HOIST AND TROLLEY ONLY

*(a)* If the application requires only the existing hoist and trolley to make lifts in excess of the rated load, then only the components and structures associated with the hoist and trolley need to be qualified for making PELs.

*(b)* An existing crane bridge or gantry may have a higher rating than its individual hoist and trolley units. Where the maximum load for the planned engineered lift exceeds the rating of the existing hoist and trolley, but is below that of the bridge or gantry, then only the hoist and trolley need to be qualified for making PELs.

## 9700 REQUIRED INTERLOCKS OR STOPS

*(a)* Temporary interlocks or stops, to restrict or prevent bridge, trolley, or hoist operation, shall be put in place for cases where the crane system could be inadvertently operated outside the qualified mode when making the planned engineered lifts.

*(b)* Specifically temporary interlocks or stops shall be provided for the following cases:

*(1)* to prevent existing crane trolley (or TLD) motion over sections of the bridge that would be stressed beyond the qualified levels

*(2)* to prevent bridge or gantry motion over sections of the building runway that would be stressed beyond the qualified levels

*(3)* to limit the existing crane trolley (or TLD) approach to the runway rail to a distance that would not increase runway stresses, end truck stresses, or wheel loadings beyond the qualified levels

*(4)* to prevent existing crane trolley movement or use of the existing crane hoist(s), when a TLD is used for making the planned engineered lifts, and when the existing bridge has only been qualified with the existing crane trolley and hoist in a stored position or nonoperating mode

*(c)* Written procedures shall be provided to address the use of temporary interlocks and stops. Procedures providing only crane operating limitations shall not be accepted in lieu of required in-place interlocks or stops.

*(d)* An acceptable electrical interlock to prevent operation of an existing crane hoist, or to maintain an existing crane trolley in a stored location, would be to physically de-energize or open the hoist or trolley unit's power or control circuits, prior to making the PEL.

## 9800 LOAD TESTING REQUIREMENTS

*(a)* Testing the crane for the PEL shall be by means of lifting the PEL load a short distance as specified in ASME B30.2.

*(b)* An additional independent test load equal to the PEL shall be required if

*(1)* the crane has not been previously tested for a load at least equal to the PEL or

*(2)* as a result of the PEL calculation review, either structural modifications of the structures, or mechanical modifications of the hoist, are required

*(c)* The full-load test and rated load test of paras. 7422 and 7423, respectively, are not required or applicable to planned engineered lifts.

## 9900 CRANE WHEEL LOADS

The PEL wheel loads shall not exceed 1.33 times the values established in accordance with para. 5452.3.

# MANDATORY APPENDIX I[1]
# ADDITIONAL REQUIREMENTS

## I-1100 GENERAL

### I-1180 Conversion Factors

See Tables I-1180-1 and I-1180-2 for conversion information relative to this Standard.

## I-4200 MATERIALS AND CONNECTIONS

### I-4250 Connections

#### I-4251 Welded Connections

**I-4251.2 Qualification of Impact Tests — Welding Procedures.** Impact qualification of materials in Group I of Table 4.1.1 of AWS D1.1 shall be considered as procedure qualification for welding other steels in these classes or combinations of them having a lower minimum yield strength. Impact qualification of materials in Group II of Table 3.1 of AWS D1.1 shall be considered as a procedure qualification for welding of material of the specification and grade, class, or type in Group II to which the specimen is certified or combinations of this material with materials in Group I, or combinations of materials in Group I with a lower yield strength. Impact qualifications of materials in Group II, III, or of Table 3.1 of AWS D1.1, which are postweld heat treated per para. 4251.5 for production welding, shall be conducted on a specimen that has been postweld heat treated to the same procedure as production welding.

Qualification for all weld types covered by a procedure shall be obtained by the welding of a full penetration butt weld with any joint preparation allowed by the procedure. The effective throat of the weld in the qualification test shall equal or exceed the maximum covered by the procedure, except that qualification with a 2½ in. thick plate shall qualify welds of unlimited size which have the same postweld heat treatment. If the procedure covers welding vertically from the bottom up, the test plate shall be welded in that position. Otherwise, the welding position is optional. The heat input shall be as near as possible to the maximum permitted by the procedure. The axis of the weld shall be oriented either parallel or perpendicular to the principal direction of rolling.

All specimens shall be removed from a location as near as practical to a depth midway between the surface and the center. The coupons for the heat affected zone impact specimens shall be taken transverse to the axis of the weld and etched to define the heat affected zone. The notch of the Charpy V-notch specimen shall be cut as normal to the heat affected zone as possible in the fracture plane. When the material thickness permits, the axis of the specimen should be inclined to allow the root of the notch to align parallel to the fusion line. The coupons for the base material shall be removed from the unaffected base material at approximately the same distance from the surface as the heat affected zone specimens. The axis of the base material specimens for Charpy V-notch tests shall be parallel to the axis of the heat affected zone specimens, and the axis of the notch shall be normal to the surface of the base material.

The minimum operating temperature at which the base material may be used shall be determined per para. 4212(a). Three Charpy V-notch specimens representing the heat affected zone and three Charpy V-notch specimens representing the unaffected base material shall be tested in accordance with ASTM A370 at 30°F below the minimum operating temperature at which the base material may be used. If the average mils lateral expansion value of the three heat affected zone specimens is equal to or greater than the average value for the unaffected base material specimens, the qualification test shall be considered acceptable. The welding procedure may be used for all temperatures at which qualified base materials may be used as determined by para. 4212.

The results of the impact testing shall be recorded in the Welding Procedure Qualification Record.

**I-4251.4 Nondestructive Examination Requirements — Ultrasonic Testing of Base Material and Weld Subject to Shrinkage Strains in the Through-Thickness Direction.** The welds requiring this examination shall be identified on detailed fabrication drawings with reference to the inspection procedures, acceptance criteria, and length to be examined. If the principal direction of load transfer for all load conditions defined in para. 4100 is parallel to the weld axis, 25% of the length of the weld shall be examined. For other directions of load transfer, 100% of the length of the weld shall be examined. The width of the region to be examined shall be equal to the width of the weld plus a distance on either side of the weld of at least 2.5 times the thickness of the thickest base metal subject to the shrinkage strains.

[1] This Mandatory Appendix contains requirements that shall be followed in the construction of cranes covered by the scope of this Standard. The Mandatory Appendix paragraphs have the same designators as the corresponding Standard paragraphs except for the prefix I-.

**Table I-1180-1 SI Conversion Factors**

| Quantity | English to SI Units | SI to English Units |
|---|---|---|
| Length | 1 in. = 2.54 cm<br>1 ft = 0.3048 m<br>1 mil = 25.4 μm | 1 cm = 0.3937008 in.<br>1 m = 3.2808399 ft<br>1 μm = 0.03937008 mil |
| Area | 1 in.$^2$ = 6.4516 cm$^2$<br>1 ft$^2$ = 0.09290304 m$^2$ | 1 cm$^2$ = 0.1550003 in.$^2$<br>1 m$^2$ = 10.76391 ft$^2$ |
| Volume | 1 in.$^3$ = 16.387064 cm$^3$<br>1 ft$^3$ = 0.028316847 m$^3$<br>1 gal = 3.785412 l | 1 cm$^3$ = 0.06102374 in.$^3$<br>1 m$^3$ = 35.31467 ft$^3$<br>1 l = 0.26417205 gal |
| Velocity | 1 ft/sec = 0.3048 m/s<br>1 ft/min = 0.00508 m/s<br>1 rpm = 0.1047197 rad/s | 1 m/s = 3.280839 ft/sec<br>1 m/s = 196.8504 ft/min<br>1 rad/s = 9.549297 rpm |
| Mass | 1 lb = 0.45359237 kg<br>1 ton = 1016.0469088 kg<br>1 ton = 1.016047 metric ton | 1 kg = 2.2046226 lb<br>1 kg =0.00098420653 ton<br>1 metric ton = 0.98420653 ton |
| Acceleration | 1 ft/sec$^2$ = 0.3048 m/s$^2$<br>1 std g = 9.806650 m/s$^2$ | 1 m/s$^2$ = 3.280840 ft/sec$^2$<br>1 std g = 32.174 ft/sec$^2$ |
| Force | 1 lbf = 4.44822 N | 1 N = 0.224809 lbf |
| Bending, torque | 1 ft·lbf = 1.35582 N·m | 1 N·m = 0.737562 ft·lbf |
| Pressure, stress | 1 lbf/in.$^2$ = 6894.76 Pa (N·m$^2$)<br>1 kip/in.$^2$ = 6.89476 MPa<br>1 lbf/in.$^2$ = 0.0703070 kg/cm$^2$ | 1 Pa = 0.000145038 lbf/in.$^2$<br>1 MPa = 0.145038 kip/in.$^2$<br>1 kg/cm$^2$ = 14.22334 lbf/in.$^2$ |
| Energy, work | 1 Btu = 1055.056 J (N·m)<br>1 ft·lbf = 1.35582 J | 1 J = 0.000947817 Btu<br>1 J = 0.737562 ft·lbf |
| Power | 1 hp = 745 W (J/s) | 1 W = 0.00134102 hp |
| Temperature | $t_c = (t_f - 32)/1.8$ | $t_f = (t_c \times 1.8) + 32$ |

GENERAL NOTE: For others, see ASTM E380.

Testing shall be conducted after welding and any required stress relief.

When accessible, a straight beam ultrasonic scan shall be conducted over the entire area of the plate to be examined from the side opposite the weld. The procedure should be per ASTM A578, except that the scanned area shall be as defined above. When the principal direction of load transfer is parallel to the axis of the weld, the acceptance shall be per ASTM A578, Level I. For other directions of load transfer, the acceptance shall be per ASTM A578, Level II, except that the size of the circle shall be reduced to 2 in. diameter.

When the side opposite the weld is not accessible, the base metal adjacent to the weld on all members shall be examined from the accessible sides by a straight beam ultrasonic scan. Any area of the base metal that exhibits total loss of back reflection shall be marked. If the adjacent base metal meets the acceptance criteria of ASTM A578, Level I, the weld and the base metal below the weld, which is subject to shrinkage strains, shall be examined by angle beam ultrasonic scanning. The procedure and acceptance criteria shall be per AWS D1.1, Section 6, Parts A and C. If the base metal adjacent to the weld exhibits a loss of back reflection in a position that would interfere with the normal weld scanning procedures, the alternate scanning procedures in the referenced sections may be employed. When examining the base metal below the weld, the criteria for the angle of the transducer should be similar to that for evaluating the fusion zone; i.e., the sound path should be as nearly perpendicular to any suspected laminar reflector as possible.

**Table I-1180-2 Conversion Factors for Weight in Tons**

| English to SI Units | SI to English Units |
|---|---|
| 1 ton (long) = 1.0160469 metric ton | 1 metric ton = 0.9842065 ton (long) |
| **U.S. Customary to SI Units** | **SI to U.S. Customary Units** |
| 1 ton (short) = 0.9071847 metric ton | 1 metric ton = 1.1023113 ton (short) |
| **English to U.S. Customary Units** | **U.S. Customary to English Units** |
| 1 ton (long) = 1.12 ton (short) | 1 ton (short) = 0.8928571 ton (long) |

GENERAL NOTE: For others, see ASTM E380.

## I-5100 GENERAL

### I-5110 Load Spectrum Crane Classification

**I-5111 Crane Service Data Report Form.** See Fig. I-5111 for an example Crane Service Data Report Form. (15)

## Fig. I-5111 Crane Service Data Report Form

| | CRANE SERVICE DATA RECORD | | Form Number / Sheet Number |
|---|---|---|---|
| Crane Service Data Provided By:<br>Company:<br>Plant: | Inq. No. ............ Prop. No. ........<br>Alt. No. ............. Rev. No. .........<br>Order No. .......... Job No. .......... | Type of Crane ..........................<br>Capacities and Span .................<br>ASME Crane Type ...................... | Expected Service Life for:<br>Support Structures ..................... Years<br>Gearing ................................. Years<br>Bearings ................................ Years<br>Other Machinery ....................... Years |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Hoist | | | | | | | | | Trolley | | | Bridge | | |
| | | | | Magnitude of Loss on Hoist Ropes | | | | ♦Lifting Motion (U) or ♦Lowering Motion (D) | | | | ♦Forward Motion (F) ♦Reverse Motion (R) | | | ♦Forward Motion (F) ♦Reverse Motion (R) | | |
| Crane Motion Reference Number | Type of Crane Operation or Crane Motion | Description of Load Suspended From Hoist Ropes (Lifted Load, Load Block and Material Handling Devices) | Type of Hoist Used: Main Aux. I Aux. II Aux. III | Weight of Load Block | Weight of Material Handling Devices | Weight of Lifted Load | Design Impact Factor | Indicate Direction by Symbol | Average No. of Hoist Motions/yr | Average No. of Starts and Stops of Hoist U or D/ Hoist Motion | Average Length of Hoist Motion | Indicate Direction by Symbol | Average No. of Trolley Motions/yr | Average Distance of Trolley Travel | Indicate Direction by Symbol | Average No. of Bridge Motions/yr | Average Distance of Bridge Travel |
| No. | Description | Description | Deline | Tons | Tons | Tons | Factor | | Cycles/yr | Number | ft | | Cycles/yr | ft | | Cycles/yr | ft |
| 1 | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | |

(15)

# MANDATORY APPENDIX II
# CRITERIA REQUIRED FOR STRUCTURAL QUALIFICATION OF AN EXISTING CRANE BRIDGE FOR USE WITH AN ASME NOG-1 TYPE I HOIST AND TROLLEY

This Mandatory Appendix provides criteria to structurally qualify an existing EOCI #61 or CMAA Specification No. 70 crane bridge to support an ASME NOG-1 Type I trolley and hoist for handling critical loads. If loadings on the bridge increase as a result of the new ASME NOG-1 Type I trolley and hoist, these loadings shall be evaluated, and as necessary, modifications shall be made to the bridge, all in accordance with this Mandatory Appendix. This approach parallels the NRC guidance for modification of existing cranes for compliance with NUREG-0554, as presented in NUREG-0612, Nonmandatory Appendix C.

The runway and runway support structure also require an evaluation to ensure that they are designed to support the crane with a lifted load for a credible seismic event. This runway and runway support structure evaluation is not covered under this Mandatory Appendix.

This Mandatory Appendix addresses the quality assurance, design documentation, inspection, and testing requirements for the structural qualification of an existing bridge, as well as the basic criteria for any required structural modifications of an existing bridge, all to support a new NOG-1 Type I trolley and hoist (see Tables II-1 and II-2).

**Table II-1 Criteria Required For Structural Qualification of an Existing Crane Bridge for Use With an ASME NOG-1 Type I Hoist and Trolley**

| Topic | Subtopic | Criteria |
|---|---|---|
| A. Quality assurance requirements | Required for activities addressed in this Mandatory Appendix | The Quality Assurance program for the design documentation, inspections, NDE, and load testing associated with the structural qualification of an existing bridge, as well as for any required structural bridge modifications, shall conform to the requirements of para. 2100(a) of this Standard. |
| B. Design documentation requirements | (1) Required documentation of the crane bridge design specification | The existing crane bridge design specification shall be verified as being either EOCI #61 or CMAA Specification No. 70, 1975 or later. [Note (1)] |
| | (2) Required documentation of the crane bridge welding standard | The existing crane bridge welding standard shall be verified as having been either AWS D1.1 or AWS D14.1 from the original manufacturer's drawings, calculations, documented design standards, etc. See item D.(2) if it cannot be confirmed that the crane was welded to either AWS D1.1 or AWS D14.1. |
| | (3) Required CMAA operating load calculations | Bridge structural calculations verifying compliance with CMAA Specification No. 70 for the design rated load are required.<br>These calculations shall be to the existing bridge's original CMAA specification, and to the original specified crane service class, unless use with the new Type I trolley and hoist warrants a different service class.<br>(a) Existing CMAA structural calculations are acceptable provided the existing trolley loadings envelope the new trolley loadings on the existing bridge, the effects of any change in service class can be addressed, and any subsequent structural modifications to the bridge have been addressed.<br>(b) New CMAA structural calculations are required if any of the following cases exist:<br>(1) CMAA Structural calculations do not exist.<br>(2) Loadings from the new trolley exceed those of the original trolley.<br>(3) The bridge was originally designed to EOCI #61.<br>(4) The existing bridge was structurally modified without calculations confirming CMAA compliance.<br>(c) If new CMAA structural calculations are required, then design input to these calculations shall be based upon the Supplemental Criteria B(3)-1 of this Mandatory Appendix. |
| | (4) Required seismic load calculations | Bridge seismic calculations verifying compliance with the plant's seismic licensing basis are required, noting that this calculation must have included the maximum credible critical load. [Note (2)]<br>(a) Existing bridge seismic calculations are acceptable provided<br>(1) The maximum credible critical load was used in the existing calculation.<br>(2) The trolley mass has not increased.<br>(3) Substantial modifications to the bridge have not been made that would invalidate the existing seismic calculation.<br>(4) The existing calculation confirms that the bridge and trolley would not be dislodged from their rails by design seismic loads.<br>(b) If new bridge seismic calculations are required, then they shall be in accordance with para. 4150 of this Standard. |

**Table II-1 Criteria Required For Structural Qualification of an Existing Crane Bridge for Use With an ASME NOG-1 Type I Hoist and Trolley (Cont'd)**

| Topic | Subtopic | Criteria |
|---|---|---|
| | (5) Other load calculations (that may be required) | (a) *Design (Stored) Wind Loads.* If applicable, such as for cranes stored outdoors, calculations shall verify that the bridge can accommodate the out-of-service (i.e., the crane is unloaded and not operating) wind load criteria of one of the following:<br>(1) the stored wind load criteria of CMAA Spec. No. 70, 1983 or later, under the load case 3, or<br>(2) the design wind load criteria of this Standard, for the load case $P_{C9}$ in para. 4140(c).<br>(b) *Tornado Wind Loads.* If applicable, based upon the plant's licensing basis, calculations shall be provided to verify that the bridge can accommodate the tornado load criteria of this Standard, for the load case $P_{C14}$ in para. 4140(d).<br>(c) *Load Hang-Up.* Calculations must be provided to verify the bridge structural integrity, for the load case $P_{c16}$ in para. 4140(e), unless one of the following conditions is met:<br>(1) Interlock circuitry is provided preventing movement of the bridge and trolley while hoisting as addressed in Nonmandatory Appendix C of NUREG-0612, or<br>(2) The hoist is not capable of producing loads greater than 125% of rated capacity, including machinery inertia loads. |
| C. Inspection requirements | Crane bridge inspections | (a) *ASME B30.2 Inspection.* The crane bridge structural components shall be inspected in accordance with the periodic inspection criteria of ASME B30.2. [Note (3)]<br>(1) Welds displaying deformation, cracks, or corrosion shall require the paint to be removed and shall then be given a visual inspection per AWS D1.1, with corrective action taken as needed.<br>(b) *Critical Load Path Weld Inspection.* Crane bridges requiring cold-proof testing shall have external critical load path welds visually inspected before and after the cold-proof test. See item D.(2) of this Mandatory Appendix. [Note (4)]<br>(c) All crane bridge inspections shall be documented. |
| D. NDE requirements | (1) Girder bottom cover plate butt welds | Bridge girder bottom cover plate butt welds shall be MT or PT examined per para. 7100 of this Standard, unless such welds were originally provided with a UT or RT examination. [Note (5)] |
| | (2) Other NDE requirements for welds | If it cannot be confirmed that the crane was welded to either AWS D1.1 or AWS D14.1, then additional weld NDE shall be performed based upon the Supplemental Criteria D.(2) of this Mandatory Appendix. |
| E. Load test requirements | (1) Bridge rated load testing | The crane bridge shall be given a current 125% rated load test if any of the following conditions exist [Note (6)]:<br>(a) The original crane was never given a 125% rated load test.<br>(b) The original crane load test documentation indicating a test load of 125% of the design rating is not available.<br>(c) Structural modifications were required of the bridge for compliance with either CMAA Spec. No. 70 criteria, seismic criteria, or other load conditions as listed in item B.(5) above.<br>(d) The loads applied to the bridge during the original 125% load test would be exceeded with the new Type I trolley and hoist, such as due to a new higher rating. [Note (7)] |

## Table II-1 Criteria Required For Structural Qualification of an Existing Crane Bridge for Use With an ASME NOG-1 Type I Hoist and Trolley (Cont'd)

| Topic | Subtopic | Criteria |
|---|---|---|
| | (2) Bridge cold-proof load testing | Cold-proof testing, where the crane bridge is given a 125% load test, at a temperature that will become the minimum operating temperature for the crane, is required, unless one of the following criteria is met:<br>(a) Bridge load-supporting structural materials meet the fracture toughness criteria of para. 4200 of this Standard.<br>(b) The crane will only be operated at a temperature of 70°F or higher, as discussed in NUREG-0612, Nonmandatory Appendix C.<br>See item C.(1)(b) for weld inspection criteria if cold-proof testing is required. |
| F. Bridge modifications (if required) | (1) As required to meet CMAA 70 criteria | Structural modifications if required by item B.(3), to provide compliance with CMAA Spec. No. 70, shall require all new materials and connections to be per para. 4200 of this Standard, with testing and inspections for all new materials and connections being per Section 7000 of this Standard. |
| | (2) As required to meet seismic criteria | Structural modifications if required by item B.(4), to provide seismic compliance, shall require all new materials and connections to be per para. 4200 of this Standard, with testing and inspections for all new materials and connections being per Section 7000 of this Standard. |
| | (3) As required to address other loading criteria | Structural modifications if required by item B.(5), to address design (stored) wind loads, tornado loads, or load hang-up loads, shall require all new materials and connections to be per para. 4200 of this Standard, with testing and inspections for all new materials and connections being per Section 7000 of this Standard. |

NOTES:
(1) The 1971 and 1975 issues of CMAA Spec. No. 70 shall be considered equivalent.
(2) As stated above, the runway and runway support structure, which is not covered by this Manatory Appendix, must also be seismically qualified for the case where the crane is lifting the maximum credible critical load.
(3) For this Mandatory Appendix, a structural member shall consist of plates and shapes, as well as any connecting welds, bolts, nuts, pins, or rivets.
(4) The critical load path for the bridge (from the bridge wheels to and including the trolley rails) is that area of the bridge that should a failure occur, the bridge would no longer be able to support the hoist and trolley.
(5) If a current MT or PT surface examination is required and this examination indicates a possible issue with weld quality, then these welds shall be 100% volumetrically inspected per para. 7100.
(6) The 125% rated load test as addressed here meets the static load test criteria of NUREG-0554.
(7) Requirements of this Mandatory Appendix do not address load testing of the new Type I trolley and hoist, where such tests may be performed in either the shop or the field once installed on the existing bridge.

## Table II-2 Supplemental Criteria Required for Structural Qualification of an Existing Crane Bridge for Use With an ASME NOG-1 Type I Hoist and Trolley

| Topic | Supplemental Criteria |
|---|---|
| B(3)-1<br>Design input to new CMAA structural calculations | If structural design details from the original manufacturer, by means of drawings, calculations, documented design standards, etc., are not available or insufficient to generate the new CMAA calculations, then field measurements shall be taken to verify the design configuration and member sizes. For internal members of structural components (e.g., girders, end ties, gantry legs, etc.) that are not readily accessible, minimum possible member sizes shall be used or sizes shall be determined by making access holes that are sized so that the structural integrity of the member is not affected. All member sizes determined by such inspections shall be documented.<br>Material properties, including welds and bolts, as used in generating the new CMAA calculations shall be based upon one or more of the following:<br>(a) Materials specified on manufacturer's drawings.<br>(b) Documentation provided by the original manufacturer.<br>(c) Material test reports of the subject members.<br>(d) If weld electrodes are unknown, E60 properties shall be assumed.<br>(e) If structural material is unknown, yield strength of 30 ksi shall be assumed.<br>(f) If bolts are not identified on the manufacturer's drawings, or by head markings, bolts equivalent to A307 bolts shall be assumed. |
| D(2)-1<br>Additional NDE of welds (if required) | Additional NDE of welds, for welding not performed to either AWS D1.1 or AWS D14.1, shall be as follows, unless the maximum weld stress or, for members subject to repeated loads, the weld stress range (maximum stress minus minimum stress) is 8,000 psi or less:<br>(a) External Welds<br>(1) Critical load path butt welds in tensile stress areas shall be 100% volumetrically inspected per para. 7100.<br>(2) All external accessible fillet welds within the critical load path shall be visually inspected for workmanship. Areas displaying poor workmanship shall have the paint removed and visually reinspected per the requirements of AWS D1.1, and corrective action shall be taken as needed.<br>(3) A minimum of 10% of the total length of each accessible critical fillet weld in the critical load path greater than 10 in. shall be subjected to magnetic particle test (MT) or dye penetrant test (PT) per AWS D1.1 requirements. If unacceptable indications are found, then an additional 25% of the weld lengths shall be inspected, and corrective actions shall be taken. If the additional 25% inspection finds additional unacceptable indications, then the weld shall be inspected 100%, and corrective actions shall be taken.<br>(b) Internal Welds<br>(1) A minimum of 10% of the internal fillet welds within the critical load path shall be visually inspected for workmanship. Areas displaying poor workmanship shall have the paint removed and be visually reinspected per the requirements of AWS D1.1, and corrective actions shall be taken as needed. If unacceptable indications are found, then an additional 25% of the weld lengths shall be inspected, and corrective actions shall be taken. If the additional 25% inspection finds additional unacceptable indications, then the weld shall be inspected 100%, and corrective actions shall be taken. |

# NONMANDATORY APPENDIX A[1] RECOMMENDED PRACTICES

## A-3240 Coatings and Finishes

### A-3241 Surface Considerations

**A-3241.1 Profiles.** When preparing surfaces for coating with inorganic zinc systems, an important consideration for proper adhesion is the number of peaks per unit area of surface. The required 5% inclusion of grit, when shot blasting, is established to provide the desired degree of roughness for these systems. Higher or lower percentage inclusions of grit may be necessary depending on numerous conditions, such as the age of the working mix at a given facility. Lower levels will require the Purchaser's approval. This approval may be obtained by a review of a sample of the mixture to be used and/or a sample panel prepared per the crane specification requirements with the intended mixture.

**A-3241.2 Moisture.** Figure A-3241.2-1 may be used as a quick reference guide to establish when the ambient conditions will allow painting or surface preparation. Better determination can be made using more precise hygromatic charts for the exact conditions at any specific time.

**A-3242 Fillers.** To minimize rust staining and similar types of problems, small spaces between abutting parts may be filled using a qualified (for Category A coating) filler compatible with the coating system and acceptable to the coating manufacturer. Seal welding may also be used for this condition where permitted by the design of adjacent structural welds.

### A-3243 Deviations and Corrections

**A-3243.1 General Requirements.** Corrections of deviations are not intended to be limited to the following. Alternative methods of correction may be used where accepted by the coating manufacturer and the purchaser.

*(a)* Any deviations in the coating system or surface preparation may be corrected by repreparation and recoating of the entire piece or component in accordance with the original requirements.

*(b)* Brush or roller application may be used in limited areas of repair.

*(c)* Areas damaged during shipment or erection may be corrected by the purchaser in accordance with these methods.

**A-3243.2 Correction of Deviations in Blasted Surfaces**

*(a)* Surface imperfections detected during or after the coating process, such as weld flaws, delaminations, scabs, and slivers, shall be corrected with methods approved by the manufacturer's design engineer.

*(b)* Gouges in surfaces may be repaired by the use of appropriately qualified caulking compounds with the approval of the manufacturer's design engineer. Gouges shall not be filled using these compounds if the area is to be overcoated with inorganic zinc. These areas may be filled after application and curing of the inorganic zinc systems where the two materials are compatible.

**A-3243.3 Correction of Deviations in Coating During Coating Application**

*(a)* Runs and sags may be corrected during coating application by either brushing out the excess material to give a smooth film within the required thickness range or by brushing out and reapplying additional coating within the specified film thickness range.

*(b)* Areas not receiving the necessary wet film thickness may be immediately recoated before flash drying occurs. For inorganic zinc systems, if flash drying has occurred, the area to be recoated shall be cured and then sweep-blasted before additional coating. If recoating of the system is delayed beyond the maximum allowed recoat time established by the coating manufacturer, the coating manufacturer shall be contacted to determine an acceptable recoat procedure.

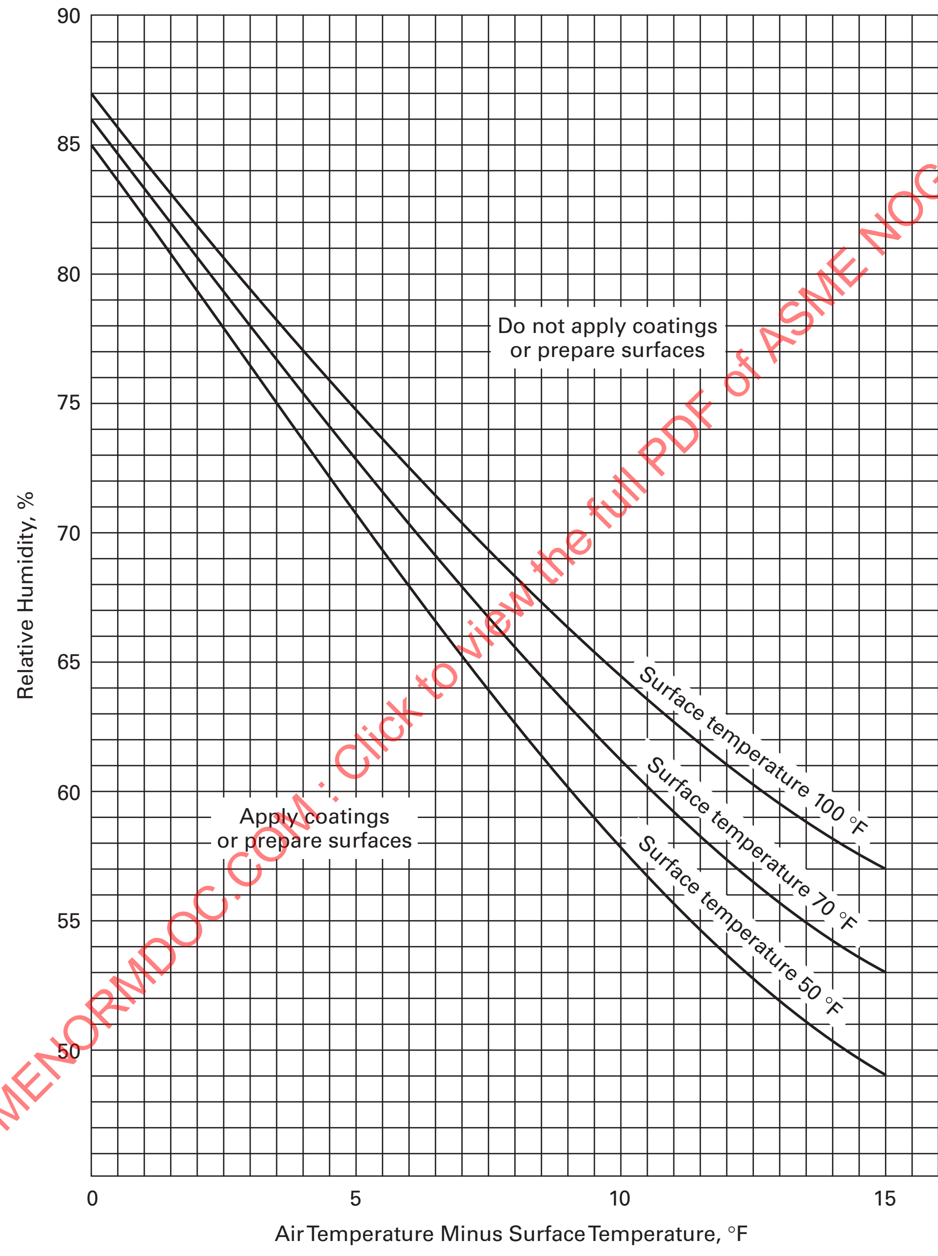
*(c)* For other than inorganic zinc systems, recoating can be performed any time after the time interval indicated by the coating manufacturer. If an extended period of delay occurs until recoating, the surfaces shall be cleaned of dirt, oils, grease, dust, and other contaminants by sweeping, brushing, wiping, using pressurized air, scraping, solvent cleaning, steam cleaning, or any combination of these or similar methods as appropriate for the contaminants involved.

**A-3243.4 Corrections of Deviations in Coating After Curing**

*(a)* Overspray may be removed by sanding, wire screening, or other appropriate means.

[1] This Nonmandatory Appendix provides information or guidance for the use of this Standard. The Nonmandatory Appendix paragraphs have the same designators as the corresponding Standard paragraphs, except for the prefix A-.

**Fig. A-3241.2-1 Ambient Conditions Chart**



(b) Discontinuities detected in other than inorganic zinc coatings may be corrected by light sanding, removal of all dust and chalk, and solvent wiping. Where not detrimental to the coating being used, additional coating material may then be applied by brush and worked to fill discontinuities.

(c) Gouges or scratches (including areas damaged due to the use of certain destructive inspection instruments) may be repaired by using a compatible filler or patching compound and sanded smooth when necessary. Before application of the filler, all loose coating shall be removed and the area feathered a minimum of 2 in. onto the film coating.

(d) Runs and sags not repaired while coating is wet may be removed by sanding or grinding. If occurring in the prime coat and upon removal the necessary minimum film thickness is maintained, recoating of additional primer is not required. Where additional coating is required, full-bodied or thinned coats may be applied in accordance with the requirements of the coating manufacturer. The application of a thinned coat may be used to improve the appearance of repaired areas.

(e) Localized blistering may be corrected by power sanding or grinding to firm coating or substrate. After grinding, a needle gun should be used to roughen the surface. Edges shall be feathered a minimum of 2 in. onto the firm coat. All dust and chalk shall be removed, and, where not detrimental to the coating, the area shall be solvent wiped. The area may then be recoated by an appropriate method.

(f) Film thickness below the specified minimum may be corrected as indicated in para. A-3243.3 or by removal of all material back to bare substrate and repreparation and application in accordance with the original requirements.

(g) Localized areas with film thickness above the specified maximum may be reduced by sanding or grinding. For inorganic zinc systems, wire screening down to the required thickness may be done if the coating is acceptable, except for the excess thickness. An example of this would be the case of an inorganic zinc coating that exhibits no mud cracking but exceeds the required film thickness. If the excess film thickness is considered by the coating manufacturer and the purchaser to not be detrimental to the integrity of the system, the system may be accepted with the excess film thickness at the discretion of the purchaser. If the excess film thickness is considered by the coating manufacturer and the purchaser to be detrimental to the integrity of the system, the system shall be removed to a previously acceptable film or to base metal as recommended by the coating manufacturer.

## A-7600 DOCUMENTATION

This subsection defines recommendations for the collection, storage, and maintenance of Quality Assurance Records applicable to the procurement, design, manufacture, shipment, receipt, storage, installation, and start-up of Types I and II cranes.

Type III cranes should require a records collection, storage, and maintenance system consistent with their procurement documents.

### A-7610 Manufacturer

The crane manufacturer should establish a system for the administration of the collection and temporary storage of records received and generated during the design, manufacture, and shipment of the crane.

**A-7611 Records Received.** The crane manufacturer will typically receive the following types of records:

(a) material test reports

(b) nondestructive examination (NDE) reports

(c) NDE inspector and examiner qualifications in accordance with SNT-TC-1A

(d) performance test reports

(e) other test reports as generated by subsuppliers

**A-7612 Records Generated.** The crane manufacturer will typically generate the following types of records:

(a) material test reports

(b) NDE reports

(c) NDE inspector and examiner qualifications in accordance with SNT-TC-1A

(d) performance test reports

(e) nonconformance reports

(f) supplier deviation requests

(g) load summary report

**A-7613 Records Submitted to Owner.** The following Quality Assurance Records should be submitted to the owner's designated representative for Types I and II cranes. Additional requirements for records may be included in the crane procurement documents.

**A-7613.1 Records Submitted During Design and Manufacture**

(a) assembly and outline drawings

(b) electrical schematics and wiring diagrams

(c) seismic calculations

(d) supplier deviation requests

(e) load summary report (see para. 4140)

(f) inspection and test plan

**A-7613.2 Records Submitted Upon Completion of the Crane**

(a) material test reports as required by Table 7210-1 or Table 7210-2

(b) NDE reports as required by Table 7210-1 or Table 7210-2

(c) radiographic film as required by Table 7210-1 or Table 7210-2

(d) wire rope breaking strength report(s) for hoisting rope(s)
(e) hook load test report(s) for Type I hook(s)
(f) shop no-load test report for the crane, mechanical and electrical
(g) approved supplier deviation requests
(h) Certificate(s) of Conformance as required by Table 7210-1 unless otherwise provided for in the crane procurement document
(i) weld filler material Certificates of Conformance to typical values per Table 7210-1 and Table 7210-2 to include heat or lot numbers unless otherwise provided for in the crane procurement document
(j) general Certificate of Conformance to the crane procurement documents
(k) NEMA test reports for motors and brakes as required by para. 7220

**A-7614 Records Custody.** The crane manufacturer should prepare and maintain Quality Assurance Records required for submittal to the owner or the owner's designated representative. Copies of these records should be retained by the manufacturer until they have been conveyed to and received by the owner/operator.

**A-7615 Records Retention.** The crane manufacturer should retain the following design and manufacturing records in accordance with Section 2000, unless copies of these records are provided to the owner or the owner's designated representative:
(a) design drawings
(b) bill of materials
(c) design calculations
(d) major defect repair record
(e) nonconformance reports
(f) welding procedures

## A-7620 Intermediate Storage

Those responsible for storage of the crane should establish a system for the collection, storage, and submittal of Quality Assurance Records to the owner or owner's designated representatives in accordance with Section 2000.

**A-7621 Records Received.** Those responsible for the storage of the crane should receive test reports as generated by subsuppliers.

**A-7622 Records Generated.** Those responsible for the storage of the crane should generate the following types of records:
(a) storage reports
(b) storage personnel qualification records
(c) test equipment calibration records
(d) test deviation or exception records
(e) inspection and examination records
(f) nonconformance reports
(g) repair reports

**A-7623 Records Submitted to Owner.** The following Quality Assurance Records should be submitted to the owner or the owner's designated representative for Types I and II cranes.

**A-7623.1 Records Issued During Storage**
(a) storage reports
(b) nonconformance reports
(c) repair reports

**A-7623.2 Records to Be Issued at Time of Shipment**
(a) storage reports
(b) inspection and examination records
(c) nonconformance reports
(d) repair records

**A-7624 Records Retention.** Those responsible for the storage of the crane should make provisions for retention of those records as listed in para. A-7623 in accordance with Section 2000 until they have been conveyed to and received by the owner/operator.

## A-7630 Constructor/Erector

Those responsible for construction/erection of the crane should establish a system for collection, storage, and submittal of Quality Assurance Records to the owner or the owner's designated representative in accordance with Section 2000.

**A-7631 Records Received.** Those responsible for the construction/erection function of the crane should receive test reports as generated by subsuppliers.

**A-7632 Records Generated.** Those responsible for the construction/erection function of the crane should generate and submit to the owner or the owner's designated representative the following types of records:
(a) records of high-strength bolt torquing
(b) NDE reports and procedures
(c) weld repair procedures and results
(d) weld fit-up reports
(e) weld location diagrams
(f) welding procedures
(g) welding procedure qualification and results
(h) welding filler metal material reports including heat and lot numbers
(i) welding material control procedure
(j) welder qualifications
(k) lifting and handling equipment test procedures, inspection, and test data
(l) data sheets or logs on equipment installation, inspection, and alignment
(m) lubrication records
(n) documentation of testing performed after installation and prior to system's conditional acceptance

(o) electrical field workmanship checklist or equivalent logs

(p) instrument calibration results, including test equipment

(q) as-built drawings and records

(r) field audit reports

(s) field quality assurance manuals

(t) final inspection reports and releases

(u) nonconformance reports

(v) start-up test procedures and results

(w) periodic checks, inspections, and calibrations performed to verify that surveillance requirements are being met

**A-7640 Owner/Operator**

The owner/operator should establish a system for the collection, storage, and maintenance of Quality Assurance Records for Types I and II cranes in accordance with Section 2000.

# NONMANDATORY APPENDIX B[1]
# COMMENTARY

## B-4100 GENERAL

### B-4130 Description of Loads

**B-4132 Credible Critical Load.** The analysis and design of structures can be approached in two ways: *deterministically*, when the loads that a structure must sustain are evident physical loads (like the weight of the materials of the structure or the occupants), and *probabilistically*, when there is need to consider loads like flood or earthquake that occur infrequently, if at all. Since most engineers, owners, and regulatory groups are more familiar with the deterministic approach to design, the consideration of earthquake, extreme winds, floods, and other infrequently occurring loads is reduced to the selection of design bases, which prescribe quantitative loads to be considered in design. Once a design basis is selected for an event, design proceeds in a deterministic way without regard to probabilistic considerations.

In deterministic design, design factor is a meaningful concept. Stresses due to design loads can be compared to allowable stresses to provide a measure of capability of the final design. In probabilistic design, the probability of occurrence of a load and the probable material properties can be considered with a previously accepted probability of failure to obtain a different measure of capability. There is insufficient experience with this approach at this time to allow its general, unrestricted use. As a result, when infrequently occurring phenomena are considered in design, probabilistic considerations are confined to the selection of a design basis, after which the normal deterministic methods of engineering and design may be employed.

Probabilistic considerations are fundamental in the formulation of design bases for nuclear power plants. As a reference, Section 2.2.3 of the Nuclear Regulatory Commission's Standard Review Plan states:

> The identification of design basis events resulting from the presence of hazardous materials or activities in the vicinity of the plant is acceptable if the design basis events include each postulated type of accident . . . for which . . . the probability . . . exceeds . . . $10^{-7}$ per year.

The application of this principle in the engineering of nuclear power plants may be found, for example, in Regulatory Guide 1.115, "Protection Against Low Trajectory Turbine Missiles."

The basic principle above applies in the seismic analysis and design of cranes for nuclear power plants. Suppose that a crane makes only one kind of lift, a load, *W*, once per year for a duration of *t* hours. In the formulation of design bases for this crane, earthquake with load on the hook is credible under the SRP criterion above if

$$t/8{,}760 \times S_p \geq 10^{-7}$$

where

$S_p$ = probability of occurrence of a seismic event

Obviously, the overall level of safety of the crane design can be increased or decreased by changing the $10^{-7}$ per unit per year criterion throughout the design. It is not necessarily meaningful, however, to consider combinations of earthquake and load on the hook having a combined probability of, e.g., $10^{-9}$ criteria in a plant designed to a $10^{-7}$ criteria.

Assuming that probability criteria are established, there are other aspects of seismic design of cranes which require further consideration. Most cranes will have several expected lifts each year, with each lifting having a weight and duration. Determination of credible conditions of earthquake and load on the hook requires that the weight and duration of several loads be factored into the design basis.

In recognition that probability concepts may be employed to establish safe design loads and reduce over conservations, terminology, symbols, and equations are given in terms of credible critical load (defined in para. 1150). The purchaser has the option of specifying the heaviest critical load as the credible critical load, or of performing probabilistic calculations to establish the weight of lifted load that should be considered in combination with OBE, and that should be considered in combination with SSE, or of specifying the range of loads that should be considered for varying magnitudes of earthquakes, from magnitude less than OBE up to SSE.

## B-4200 MATERIALS AND CONNECTIONS

### B-4210 Base Materials

**B-4212 Fracture Toughness — Material.** Impact testing of material is based on the procedures in Subsection ND-2300 or NC-2300 of Section III, Division 1, of the ASME Boiler and Pressure Vessel Code. Either the drop-weight test per ASTM E208 or the

[1] This Nonmandatory Appendix provides commentary to the correspondingly designated Standard paragraphs.

Charpy V-notch test per ASTM A370 may be used. These rules apply to those members essential to structural integrity.

Table 4212-1 is extracted from Table ND-2311(a)-1 of Section III, Division 1. Certain exemptions from testing are allowed. These exemptions are based on those in the referenced portions of Section III, Division 1, except for the exemption of members that experience only compression or tensile stresses below 6,000 psi for all conditions of loading. This exemption is based on Section III, Division 1, Subsection NF-2300, and the fact that tensile stresses are required for unstable crack propagation. The consideration of residual stress is necessary to apply this exemption.

The original development of the requirements in Section III was reported in Welding Research Council Bulletin No. 175, "PVRC Recommendations on Toughness Requirements for Ferritic Materials," by the PVRC Ad Hoc Task Group on Toughness Requirements, August 1972. The requirements are not a simple transition temperature approach but are based on linear elastic fracture mechanics concepts. A toughness characteristic of the material, KIR, which is lower than or equal to the static initiation fracture toughness under slow load conditions, the dynamic initiation fracture toughness under fast load conditions, and the crack arrest fracture toughness, was correlated with the NDT determined from drop weight tests. The selection of test temperatures, acceptance criteria, and exemptions from testing in the code are soundly based on conservative criteria.

With the broadening of this work to cover nuclear facilities and the possible application of cranes in areas of extremely high radiation in facilities of new or unforeseen design, a warning has been included on the need to define special toughness acceptance criteria for unusual radiation.

The materials in Table 4211-1 include those commonly used for those structural components vital to structural integrity. Provision is made to allow other suitable materials that are not listed. It should be noted that, dependent on the minimum operating temperature specified for a particular application, some materials may require special processing to meet the acceptance criteria required. The use of alternate materials that include the special processing as a part of the base specification can often solve problems of availability.

### B-4220 Fastener Materials

**B-4222 Fracture Toughness — Fasteners.** The acceptance criteria in Table 4222-1 are based on the criteria in Table 4212-1 with an allowance for the difference in cooling rates for rounds versus plates and the yield strengths involved.

### B-4230 Welding Materials

**B-4232 Fracture Toughness — Welding Material.** The acceptance criteria defined in this section are based on allowing the use of the test procedures in the filler metal specification with a suitable temperature offset to match the acceptance criteria required for the base material with which the filler metal is normally used as a matching material. This will allow the tests performed by the filler metal manufacturer to be used as a basis for acceptance whenever possible.

### B-4250 Connections

#### B-4251 Welded Connections

**B-4251.2 Qualification Impact Tests — Welding Procedures.** When materials are welded, the heat affected zone of the base material may show reduced toughness. This subsection provides for the qualification of the welding procedures to ensure that the toughness of the heat affected zone is compatible with that of the unaffected base metal. Paragraph I-4251.2 is extracted from the requirements in the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsections NC-4300 and ND-4300. This allows qualification of a welding procedure and would not require individual impact tests on each crane manufactured.

**B-4251.4 Nondestructive Examination Requirements — Lamellar Tearing.** The most suitable nondestructive inspection technique for the detection of lamellar tears in completed, highly restrained joints is ultrasonic testing. The use of ultrasonic inspection before fabrication does not effectively evaluate the susceptibility to lamellar tearing.

There are no generally accepted acceptance criteria for this test in current use. The criteria used herein assume that if the principal direction of load transfer is parallel to the weld axis (e.g., transverse shear), the presence of lamellar tears is less critical than if the load transfer is in a direction that would tend to open the tear. This correlates with field experience. It is also assumed that if access to examine the base metal by the straight beam method is limited, the joint is more highly restrained and a more extensive examination is required. Both the weld and base metal must be inspected by the method specified. The acceptance criteria are a combination of the requirements in ASTM A578 for the base material and AWS D1.1 for the weld metal. The designer should refer to "Commentary on Highly Restrained Welded Connections," AISC Engineering Journal, Third Quarter, 1973, and J. C. M. Farrar, and R. E. Dolby, "Lamellar Tearing in Welded Steel Fabrication," The Welding Institute, for a more extensive discussion and guidelines for avoiding joints that are susceptible to lamellar tearing. It should also be pointed out that special processing of some materials will reduce the tendency to tearing when a restrained joint cannot be avoided. The use of materials that include this processing does not relieve the manufacturer from nondestructive examination until a more extensive history of usage can be accumulated to justify exemptions.

**B-4251.5 Postweld Heat Treatment.** Lamellar tearing occurs during the welding process, and, while a thermal stress relief applied after welding will not prevent it, the treatment will relieve residual stresses that may, in combination with service stresses, tend to open any tear that may develop. The imposition of the toughness criteria in para. 4212, which include the consideration of existent flaw size, and, for critical loads, the crack arrest fracture toughness, also work to this end.

A very important reason for specifying postweld heat treatment in many applications is to avoid stress corrosion cracking. However, for normal environments and the accepted materials, this is not a significant design factor for the structural components of cranes. This treatment also is often specified to improve the dimensional stability of a weldment during machining. There are, however, other methods of controlling the dimensions of the structural components of cranes, and the distortion produced during treatment is not an inconsiderable objection to a blind requirement to postweld heat treat all structural components.

Postweld heat treatment relieves the residual stresses in the vicinity of the weld and tempers the heat affected zone. The resistance to brittle fracture can thus be improved for most materials that are susceptible to unstable crack propagation below yielding. Postweld heat treatment also can be shown to have favorable effects on the fatigue resistance of welded structures. The toughness requirements herein should eliminate failures of the first type, and the use of the fatigue design in CMAA 70 and AWS D1.1, Section 2, which is based on actual tests of nonstress-relieved components, should eliminate failures of the second type. The imposition of the requirement for postweld heat treatment should be viewed as providing an additional design factor for these conditions.

**B-4252 Bolted Connections.** The requirements in this Section are based on the cited reference and J. W. Fisher and J. H. A. Struik, "Guide to Design Criteria for Bolted and Riveted Joints," 1974, and W. K. Boyd, and W. S. Hyler, "Factors Affecting Environmental Performance of High-Strength Bolts," Journal of the Structural Division, ASCE, July 1973. The joints vital to the structural integrity of Types I and II cranes should be made with properly pretensioned high-strength bolts. Criteria are presented for qualifying bolts other than ASTM A325 or A490 in pretensioned joints which may be required to meet the toughness acceptance criteria contained herein. Bearing connections may also be employed for other connections with any accepted bolts. When pretensioning is not employed, provisions should be made to prevent loosening during normal operation.

## B-5400 COMPONENT DESIGN

### B-5470 Analytical Procedures

**B-5474 Determination of Stress Fluctuation Ratio.** For determining stress fluctuation ratio, it should be observed that the stress having the maximum absolute magnitude (regardless of whether it is a tension, compression, shear, combined, or equivalent stress) is to be considered positive in all cases. The minimum stress is to be considered positive if it is of the same sense as the maximum stress; otherwise it is to be taken as negative, in which $R_B$, $R_N$, $R_S$, and $R_T$ also become negative. In regions of combined stress, $\sigma_{max}$ or $\tau_{max}$ should be taken as the maximum combined or equivalent stress having the maximum absolute magnitude. $\sigma_{min}$ or $\tau_{min}$ shall be taken as the absolute minimum stresses that do occur at the same location as the maximum stress.

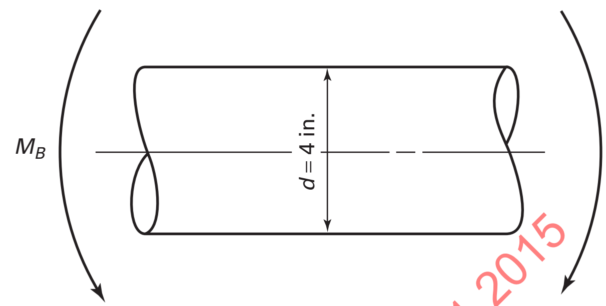
The allowable stresses in Figs. 5474-1, 5474-2, and 5474-3 are based on machined surfaces. Components with cast, hot-rolled, welded, or forged surfaces require, therefore, a reduction of the allowable stresses.

The minimum ultimate tensile strength, $\sigma_{UT}$, shall be based on the tensile strength at mid-radius for the raw material size used. Special consideration must be given to crane parts which are subjected to surface corrosion, fretting, wear, and other surface damaging effects. A reduction of the allowable stresses that are established in Figs. 5474-1, 5474-2, and 5474-3 must take place in accordance with the severity of the existing or anticipated damaging effects.

Extreme low or elevated temperatures may require a selection of special materials and a reduction of allowable stresses.

**B-5476 Basic Stress Equations.** The following examples illustrate the procedure for determining the basic design stresses when using the equations for the design of a plain pin and stepped drive shaft with a fillet radius.

**Fig. B-5476-1 Plain Pin**




**Example 1: Plain Pin** (see Fig. B-5476-1)

*Given:* Material with $\sigma_{UT}$ = 117 ksi

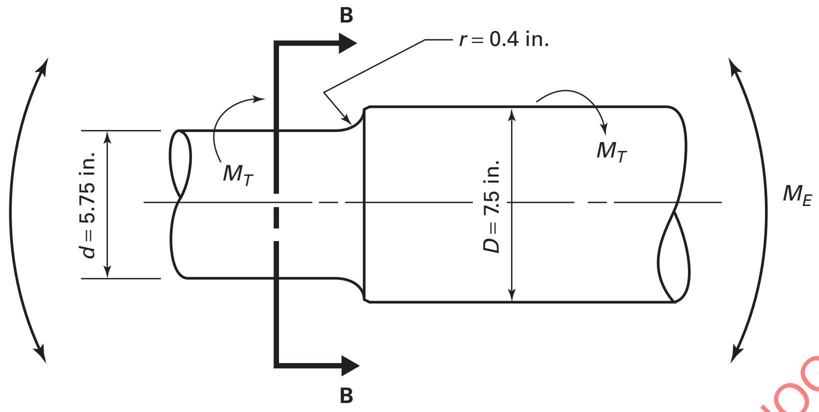
$A$ = 12.57 in.$^2$

$K_{SB}$ = $K_{SS}$ = 1.10 (example value)

$M_B$ = 130 in. kips

$P$ = 50 kips

**Fig. B-5476-2 Stepped Drive Shaft With Fillet Radius**




$R_B = R_S = +0.14$ (example value)
$S_B = 6.28$ in.$^3$

*Solution:*
From Fig. 5474-1, $\sigma_{BA} = 23.05$ ksi
From Fig. 5474-3, $\tau_A = 11.45$ ksi
$K_{NB}$ and $K_{NS} = 1.0$

$$\begin{aligned}\sigma_B &= M_B/S_B \times K_{SB} \times K_{NB}\\ &= 120/6.28 \times 1.10 \times 1.0\\ &= 22.8 \text{ ksi} < 23.05 \text{ ksi} \qquad \text{(C12-1)}\end{aligned}$$

$$\begin{aligned}\tau_S &= 1.33P/A \times K_{SS} \times K_{NS}\\ &= (1.33 \times 50)/12.57 \times 1.10 \times 1.0\\ &= 5.82 \text{ ksi} < 11.45 \text{ ksi} \qquad \text{(C16-1)}\end{aligned}$$

**Example 2: Stepped Drive Shaft With Fillet Radius** (see Fig. B-5476-2)

*Given:* Material with $\sigma_{UT} = 98$ ksi
$A = 25.97$ in.$^2$
$K_{SB} = K_{SS} = 1.10$ (example value)
$K_{ST} = 1.0$ (example value)
$M_B = 130$ in. kips
$M_T = 130$ in. kips
$P = 50$ kips
$R_B = R_S = R_T = -1.0$ (example value)
$S_B = 18.66$ in.$^3$
$S_T = 37.33$ in.$^3$

*Solution:*
From Fig. 5474-1, $\sigma_{BA} = 14.1$ ksi
From Fig. 5474-3, $\tau_A = 8.15$ ksi
From para. 5471(a), $K_{NB} = 1.43$
From para. 5471(a), $K_{NS} = 1.26$
From para. 5471(a), $K_{NT} = 1.29$

$$\begin{aligned}\sigma_B &= M_B/S_B \times K_{SB} \times K_{NB}\\ &= 130/18.66 \times 1.10 \times 1.43\\ &= 10.96 \text{ ksi} < 14.1 \text{ ksi} \qquad \text{(C12-2)}\end{aligned}$$

$$\begin{aligned}\tau_T &= M_T/S_T \times K_{ST} \times K_{NT}\\ &= 130/37.33 \times 1.0 \times 1.29\\ &= 4.49 \text{ ksi} < 8.15 \text{ ksi} \qquad \text{(C17)}\end{aligned}$$

$$\begin{aligned}\sigma_{EB} &= \sqrt{\sigma_B^2 + (\sigma_{BA}/\tau_{TA})^2 \times \tau_{ET}^2}\\ &= \sqrt{(10.96)^2 + (14.18.15)^2 \times (4.49)^2}\\ &= 13.44 \text{ ksi} < 14.1 \text{ ksi} \qquad \text{(C20)}\end{aligned}$$

$$\begin{aligned}\tau_S &= (1.33P/A) \times K_{SS} \times K_{NS}\\ &= [(1.33 \times 50)/25.97] \times 1.10 \times 1.26\\ &= 3.55 \text{ ksi} < 8.15 \text{ ksi} \qquad \text{(C16-2)}\end{aligned}$$

$$\begin{aligned}\tau_{ET} &= \tau_T + (\tau_{TA}/\tau_A) \times \tau_S\\ &= 4.49 + (8.15/8.15) \times 3.55\\ &= 8.04 \text{ ksi} < 8.15 \text{ ksi} \qquad \text{(C18)}\end{aligned}$$

$\tau_{ET}$ represents the total equivalent shear stress at section B–B.

In eq. (20), Section 5000, because of the circular section and shear load applied only in one plane, $\tau_S$ does not combine with $\tau_T$; therefore, $\rho_{ET}$ equals $\tau_T$.

**B-5477 Analytical Method for Hook of Approximate Trapezoidal Shape.** The following example illustrates the procedure for determining the maximum stress in a hook at the critical section when using the design equations. These equations have been applied to the hook section having a depth of 8 in. and a maximum width of 5 in., and the approximate shape shown in Fig. 5477-1. By choosing the area, $A_1 = A_2 + A_3$ and $A_1' = A_2' + A_3'$, the following values for the equivalent trapezoid were obtained:

$A = 34$ in.$^2$
$b_i = 5.1$
$b_o = 3.9$
$b_o/b_i = 0.765$
$l_1 = 0.25$ in.
$r_i = 4.5$

$r_o = 12.07$
$r_o/r_i = 2.68$

Using these values in eqs. (34) and (35), Section 5000,

$K_1 = 1.073$
$K_2 = 0.9930$
$K_1 - K_2 = 0.080$

Taking the load, $P$, equal to 50,000 lb, and using these values in eqs. (33), (27), and (28), Section 5000,

$S_b = 13{,}200$ psi
$S_l = 1{,}470$ psi
$S_o = 1{,}830$ psi

From eq. (30), Section 5000, the maximum stress becomes $S_{max} = 16{,}500$ psi.

Computation of the hook section using the numerical integration method results in a stress value of 16,200 psi, confirming the value obtained by the analytical method.

Similar calculations on a hook section of $9\frac{1}{2}$ in. depth and 6 in. maximum width with the same inside radius showed a figure of 11,000 psi for the analytical method and 10,900 psi for the numerical integration method. This would seem to indicate that the former is sufficiently accurate for most purposes for sections approximating the shape shown in Fig. 5477-1.

## B-6400 COMPONENT SELECTION (TYPES I, II, AND III CRANES)

### B-6470 Motors (Types I, II, and III Cranes)

#### B-6472 Motor Size Selection, AC or DC

**B-6472.3 Determination of Horsepower for Bridge Drive Motors.** The following example illustrates determination of horsepower for bridge drive motors.

*Example:*

ASSUME:

350 ton crane, empty weight = 200,000 lb

Rated speed = 60 ft/min

$a = 0.4$ ft/sec$^2$

Mech. eff. = 90% wound rotor drive

Rolling friction = 15 lb/ton

Duty Class 1 — increased resistance for slow speed and plugging

Total loaded $W_t = 450$ ton

From eq. (2), Section 6000, $hp = K_s K_a W_t V$

$K_s = 1.1$ (Table 6472.3-1)

$K_a = 0.000885$ (Fig. 6472.2-1)

Minimum 60 min $hp = 1.1 \times 0.000885 \times 450 \times 60 = 26.3$ hp

Therefore, try a 30 hp motor. Assume 20% total permanent secondary winding ohms is required by the selected type of static control.

Running $hp = 0.000455 \times 450 \times 60 = 12.3$ hp $= 41\%$ [eq. (6), Section 6000]

From Fig. 6473-1, speed = approximately 92%; therefore, gear for 60 ft/min = 1,104 rpm if a 1,200 rpm motor is used.

Check on motor using eq. (4), Section 6000 — average motor $T = 1.5$ per unit.

Motor $Wk^2 = 21$ lb-ft$^2$

Estimated brake $Wk^2 = 3.1$ lb-ft$^2$

Min. $hp = 1.1\,[(450 \times 2{,}000 \times 60)/(33{,}000 \times 1.5)] \times [(15/2{,}000) + 0.4/(32.2 \times 0.9) + (0.4/32.2) \times (24.1/67.3)] = 30.9$ hp

Equivalent load $Wk_L^2 = 900{,}000 \times [60/(2\pi \times 1{,}104)]^2 = 67.3$ lb-ft$^2$

Therefore, a 30 hp motor could be used if one of the following changes (or an equivalent combination of changes) were acceptable:

*(a)* the selected control provides 1.55 per unit average $T$ during acceleration instead of 1.5 per unit

*(b)* improve the mechanical efficiency to 95%

*(c)* reduce the acceleration rate from 0.4 ft/sec$^2$ to 0.38 ft/sec$^2$

*(d)* reduce the rated speed from 60 ft/min to 58.2 ft/min

For Table 6472.3-1, Effect of Permanent Secondary Resistance and Service Factor on AC Wound Rotor Hoist Motor Rating, assume that the mechanical $hp$ required for steady-state hoisting of rated load at rated speed is 60 hp [Table 6472.3-1, Note (3), second equation]. If the type of control has 20% total secondary resistance at full speed and $K_s = 1$, the minimum motor rating is $97/80 \times 60 = 72.75$ hp, requiring a 75 hp motor [Table 6472.3-1, Note (3), first equation]. However, if $K_s = 1.4$ in this example, the minimum is $(1.4 - 1 + 97/80) \times 60 = 96.75$ hp, requiring a 100 hp motor. Figure 6473-1 will show that with the 75 hp motor (60/75 = 0.8 per unit hp), 20% resistance will result in approximately 0.81 per unit synchronous speed or 19% slip. With the 100 hp motor (60/100 = 0.6 per unit hp), 20% resistance will result in approximately 0.87 per unit speed or 13% slip.

**B-6472.4 AC Motor Heating Calculation (See Table B-6472.4-1.).** Assume that the motor being considered has variable losses of 0.663 and fixed losses of 0.337, with a dissipation capability of 0.39 at 100% speed, 0.34 at 50% speed, and 0.29 at zero speed. (These values are based on 1.0 per unit losses corresponding to the motor rated hp and speed, with rated voltage on the primary and rings shorted.) Also assume that the control to be used has 20% fixed secondary resistance, with the regulator limiting the average accelerating torque to 150% and the average decelerating torque to 100%.

## Table B-6472.4-1 AC Motor Heating Calculation

| | Time, sec | Torque per Unit, *Tpu* | Amps per Unit, *Ipu* | Variable Losses × Time *pu* × sec: With 20% Fixed | Variable Losses × Time *pu* × sec: With *Ipu* = *Tpu* | Average Speed per Unit | Dissipation × Time *pu* × sec |
|---|---|---|---|---|---|---|---|
| Accelerate | 5.0 | 1.5 | 1.94 | 12.4 | 7.5 | 0.5 | 1.7 |
| Run | 11.8 | 0.25 | 0.4 | 1.3 | 1.3 | 1.0 | 4.6 |
| Decelerate | 4.8 | 1.0 | 2.74 | 23.9 | 3.2 | 0.5 | 1.6 |
| Time on | 21.6 | | | 37.6 | 12.0 | | |
| Rest | 50.4 | | | | | | 14.6 |
| Total | 72.0 | | | | | | 22.5 |

GENERAL NOTES:

(a) For acceleration, average slip = 0.5 and

$$I = \sqrt{1.5 \times (0.5/0.2)} = 1.94 \text{ per unit}$$

(b) For run, use minimum per unit $I$ of 0.4.

(c) For deceleration, average slip when plugging = 1.5 and

$$I = \sqrt{1.0 \times (1.5/0.2)} = 2.74 \text{ per unit}$$

(d) Fixed losses = 21.6 × 0.337 = 7.3.

(e) Total losses = 7.3 + 37.6 = 44.9 per unit kW/sec with 20% fixed ohms.

(f) Since the per unit kW/sec dissipation capability is only 22.5, the motor is not adequate.

(g) If the control increased resistance properly for acceleration and deceleration so that amps per unit equals torque per unit, the variable losses above would decrease to 12.0, and the total of 12.0 + 7.3 = 19.3 is within the 22.5 dissipation capability. With that type of control, the motor would be satisfactory.

# NONMANDATORY APPENDIX C
# NUREG-0554/ASME NOG-1 CONFORMANCE MATRIX

This Nonmandatory Appendix provides a comparison between NUREG-0554 and the related ASME NOG-1 requirements, specifically indicating a method or statement of NOG conformance to each NUREG guideline. This matrix is not a summary of all the requirements in NOG-1, in that the NOG-1 document is a comprehensive standard providing substantial and additional criteria for the design, fabrication, and testing of a Type I single-failure-proof critical load handling crane.

This document is offered for use by the owner as part of any required licensing submittal, noting that certain guidelines in NUREG-0554 are either plant specific or out of the scope of the NOG-1 document, and must be supplemented by the owner. It should also be noted that conformance with just the NOG-1 sections referenced in the matrix is neither intended nor endorsed by ASME as meeting the criteria for a single-failure-proof crane.

NOTE: When comparing NUREG-0554 and NOG-1 for conformance, refer to the text of the standards for exact wording.

NUREG-0554 Section 1 is introductory only, with no guidelines. Therefore, the conformance matrix begins with Section 2.

## NUREG-0554/ASME NOG-1 Conformance Matrix

| NUREG Section No. | Summary of NUREG Guidance | NOG-1 Paragraph No. | Method or Statement on NOG Conformance | Conforms (Yes/No) | Comments |
|---|---|---|---|---|---|
| **2. Specification and Design Guideline** | | | | | |
| 2.1 Construction and Operating Periods | Duty cycles and loading requirements are to be specified for any plant construction phase use of the crane. | 4130 | Requires the purchase specification to describe all nondead loads, including construction loads | Yes | . . . |
| | | 4140 | Identifies construction load combinations | | |
| | | 4300 | Identifies construction load allowable stresses | | |
| | | 5111 | Requires identification of loads during construction period for mechanical fatigue analysis | | |
| | | 6180 | Requires identification of electrical duty cycle or class for construction use of crane | | |
| | Allowable design stress limits of Table 3.3.3.1.3-1 of CMAA 70-75 should be met for the appropriate CMAA duty class. | 4350 | For loading cycles over 20,000, NOG-1 requires that the allowable stress range (maximum stress minus minimum stress) for repeated loads be in accordance with CMAA 70 for the appropriate service level. | Yes | Note that Table 3.3.3.1.3-1 of CMAA 70-75 pertains only to the allowable stress range for repeated loads for fatigue considerations and is independent of the allowable design stress, which is based upon a percentage of the material's yield strength. The user of NOG-1 must specify if the loading cycles exceed 20,000. |
| | Sum total of simultaneously applied loads (static and dynamic) should not result in stress levels causing permanent deformation, other than localized strain concentration, in any part of the handling system. | 4140 | Identifies the various simultaneously applied loads (load combinations), including dynamic loads, as produced by either vertical impact or seismic event | Yes | . . . |
| | | 4310 | This section addresses allowable stresses. Note that the maximum allowable stress levels permitted by NOG-1 will not cause permanent deformation other than localized strain concentrations. | | |

## NUREG-0554/ASME NOG-1 Conformance Matrix (Cont'd)

| NUREG Section No. | Summary of NUREG Guidance | NOG-1 Paragraph No. | Method or Statement on NOG Conformance | Conforms (Yes/No) | Comments |
|---|---|---|---|---|---|
| **2. Specification and Design Guideline (Cont'd)** | | | | | |
| 2.1 Construction and Operating Periods (Cont'd) | | | | | |
| | The effects of cyclic loading induced by jogging or plugging an uncompensated hoist control system should be included in the design specification. | 5310(a) | Requires consideration of all loads induced, including electrical | Yes | . . . |
| 2.2 Maximum Critical Load | A single-failure-proof crane should be designed for the maximum critical load (MCL). | 1150<br>4132(b), (d)<br>4140<br>4136<br>4000<br>5000<br>6000 | NOG-1 makes the distinction between the rated load, the critical load, and the credible critical load. For the purpose of this conformance evaluation, the credible critical load in NOG-1 is equal to the maximum critical load in NUREG. NUREG makes the distinction between the design rated load and the maximum critical load. The critical load is defined in NOG-1 as any lifted load whose uncontrolled movement or release could adversely affect any safety-related system when such a system is required for unit safety or could result in potential off-site exposure in excess of the limit determined by the purchaser. Credible critical loads are the combinations of critical loads and plant seismic events that have probabilities of occurrence equal to or more than $10^{-7}$ times per calendar year. The MCL is defined in NUREG-0554 as a load handled by a crane that can be a direct or indirect cause of release of radioactivity. | Yes | The NOG-1 definition encompasses the NUREG definition. |