ASME NUM-1–2023

(Revision of ASME NUM-1–2016)

Rules for Construction of Cranes, Monorails, and Hoists (With Bridge or Trolley or Hoist of the Underhung Type)

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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

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FOREWORD

The Committee on Cranes for Nuclear Power Plants was first established in 1976. In 1980, the scope of the committee was revised, and its name was changed to the Committee on Cranes for Nuclear Facilities. In 1983, the Nuclear Underhung and Monorail (NUM) Subcommittee was established to develop a standard to cover the design, fabrication, installation, and testing of underhung and monorail equipment used in nuclear facilities. ASME NUM-1 is the result of the subcommittee's work.

The first edition of ASME NUM-1 was approved by the American National Standards Institute (ANSI) on October 28, 1996. The second edition of ASME NUM-1 was approved by ANSI on May 3, 2000. The third edition of ASME NUM-1 was approved by ANSI on August 17, 2004. The fourth edition of ASME NUM-1 was approved by ANSI on December 22, 2009. The fifth edition of ASME NUM-1 was approved by ANSI on June 16, 2016.

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

ASME NUM-1–2023 has been reformatted and updated. The Standard comprises the following three Parts, which cover the topics and equipment listed below:

Part GR, General Requirements (applicable to all equipment)
- Environmental Conditions of Service
- Performance Requirements
- Coatings and Finishes
- Quality Assurance
- Definitions
- Referenced Codes and Standards

Part CM, Cranes and Monorails
- Structural Requirements, Cranes and Monorails (Types I and II)
- Mechanical Requirements, Cranes and Monorails (Type I)
- Electrical Requirements, Cranes and Monorails (Type I)
- Pneumatic Requirements, Cranes and Monorails (Type I)
- Marking, Cranes and Monorails (Types I and II)
- Inspection and Tests, Cranes and Monorails (Types I and II)

Part HT, Hoists and Trolleys
- Powered Wire Rope Hoists (Type IA)
- Powered Wire Rope Hoists (Type IB)
- Powered Chain Hoists (Type IB)
- Hand-Chain Hoists (Type IB)
- Under-Running Trolleys (Type IB)
- Common NDE Criteria for Hoists and Trolleys

The Standard now applies only to the enhanced safety and seismic Type I cranes and monorails, seismic Type II cranes and monorails, and enhanced safety Type I hoist and trolley units. Hoists having single failure-proof features are identified as Type IA, with those having additional safety features and increased design factors identified as Type IB. This Standard now separately and more clearly addresses the criteria for powered wire rope hoists (Type IA), powered wire rope hoists (Type IB), powered chain hoists (Type IB), manual chain hoists (Type IB), and under-running trolleys (Type IB). Type III standard equipment, which is not used for handling critical loads and is not required to withstand a seismic event, is no longer addressed in this Standard since such equipment is covered by other industry standards.

The 2023 edition of ASME NUM-1 was approved by ANSI on December 4, 2023.

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Cranes for Nuclear Facilities

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This Standard is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

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(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Standard

(4) to permit the use of a new material or process

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(c) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Standard and the paragraph, figure, or table number

(4) the editions of the Standard to which the proposed case applies

(d) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Approved cases are posted on the committee web page.

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ASME NUM-1–2023
SUMMARY OF CHANGES

Following approval by the ASME CNF Standards Committee and ASME, and after public review, ASME NUM-1–2023 was approved by the American National Standards Institute on December 4, 2023.

ASME NUM-1–2023 has been revised in its entirety.

PART GR
GENERAL REQUIREMENTS

Section GR-1
Introduction

GR-1.1 GENERAL

Design of equipment covered by this Standard shall be 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.

This Standard is comprised of three major parts:

(a) Part GR: general requirements applicable to all equipment

(b) Part CM: requirements applicable to cranes and monorails

(c) Part HT: requirements applicable to hoists and trolleys

Part CM provides criteria for the crane and monorail structures and is used in conjunction with Part HT, which provides criteria for the hoist and trolley units. Both parts require inclusion of the general criteria of Part GR for the specified crane, monorail, hoist, and trolley configurations.

GR-1.2 SCOPE

This Standard covers the following lifting and handling equipment configurations used in nuclear facilities that require enhanced safety features or seismic design features, or both:

(a) underhung cranes

(b) top-running bridge and gantry cranes with underhung trolleys

(c) traveling wall cranes

(d) jib cranes

(e) monorail systems

(f) overhead hoists

(g) hoists with integral trolleys

(h) separate underhung trolleys

Subsection GR-6.2 provides graphical depictions of the various crane, monorail, hoist, and trolley configurations addressed in this Standard.

The above cranes, whether single or multiple girder, are covered by this Standard. For multiple-girder cranes with both top-running bridge and top-running trolley, see ASME NOG-1.

GR-1.2.1 Equipment Types Covered

The handling equipment used in a nuclear facility is categorized as Type I, Type II, or Type III. This Standard addresses Type I and Type II cranes and monorails and Type I hoists and trolleys. Type II hoists and trolleys shall meet the requirements of general industry standards and the additional requirements noted in para. GR-1.2.1.2. Type III cranes, hoists, monorails, and trolleys shall meet the requirements of general industry standards. Paragraphs GR-1.2.1.1 through GR-1.2.1.3 define the three categories of equipment.

GR-1.2.1.1 Type I Equipment. Type I equipment is a crane, monorail, hoist, or trolley with enhanced safety designs and features for handling a critical load. Design and construction of Type I equipment shall be such that it will remain in place and support the critical load during and after a safe shutdown earthquake (SSE) event; however, Type I equipment does not have to be operational after this event.

There are two subtypes of Type I equipment.

(a) Type IA equipment shall incorporate single-failure-proof designs and features. The design shall be such that any credible failure of a single component will not result in the loss of capability to stop and hold a critical load.

(b) Type 1B equipment shall incorporate enhanced safety designs and features. This includes increased design factors and redundant components that minimize the potential for failure that would result in the loss of capability to stop and hold a critical load.

Table GR-1.2.1.1-1
Major Enhanced Safety Design Differences for Various Type IA and Type IB Hoist Configurations

Design of	Type IA Powered Wire Rope Hoists	Type IB Powered Wire Rope Hoists	Type IB Powered Chain Hoists	Type IB Hand-Chain Hoists
Hoisting machinery configuration	Single-failure-proof features for hoist drivetrain (see subsection HT-2.2)	No single-failure-proof features but increased design factors (see subsection HT-3.2)	No single-failure-proof features but increased design factors (see subsection HT-4.2)	No single-failure-proof features but increased design factors (see subsection HT-5.2)
Reeving arrangement	Two separate (redundant) load paths so either path supports the load (see para. HT-2.3.1)	Single load path with either single or double reeving (see para. HT-3.3.1)	Single load path providing true vertical lift (see para. HT-4.3.1)	Single load path providing true vertical lift (see para. HT-5.3.1)
Rope or chain design factor	4:1 (25% of breaking strength) for each load path [see para. HT-2.3.3(b)]	10:1 (10% of breaking strength) (see para. HT-3.3.3)	10:1 (10% of breaking strength) (see para. HT-4.3.3)	10:1 (10% of breaking strength) (see para. HT-5.3.3)
Two-block design consideration	Design accommodates two-blocking [see para. HT-2.3(a)]	Designed to prevent two-blocking with power limit switch (see para. HT-3.3.7(a)	Design accommodates two-blocking (see para. HT-4.3.1)	Design accommodates two-blocking (see para. HT-5.3.1)
Holding brake arrangement	Redundant hoist brakes: either three brakes, two brakes if there is one on drum, or two brakes if controlled braking provided with power off (see para. HT-2.3.8)	Redundant hoist holding brakes, each designed for double the load (see para. HT-3.3.6)	Redundant hoist brakes: one holding brake designed for double the load and a second braking means (see para. HT-4.3.4)	Single brake that is designed for double the load (see para. HT-5.3.4)

GENERAL NOTE: This Standard does not address Type IA powered chain hoists or Type IA hand-chain hoists. Such equipment configurations are not typically considered for use in a nuclear facility.

See Table GR-1.2.1.1-1 for the major enhanced safety design differences between various Type IA and Type 1B hoist configurations addressed in this Standard.

All trolleys addressed in this Standard, whether used with a Type IA hoist or a Type IB hoist, are Type IB trolleys with increased design factors.

GR-1.2.1.2 Type II Equipment. Type II equipment is a crane, monorail, hoist, or trolley not used in handling a critical load. Design and construction of Type II equipment shall be such that during or after a seismic event, no portion of the equipment will become dislodged in a way that will 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. The crane or monorail need not support the load nor be operational during or after such a seismic event.

GR-1.2.1.3 Type III Equipment. Type III equipment is a crane, hoist, or monorail not used to handle a critical load. No seismic considerations are necessary and no single failure-proof features are required. This Standard does not address Type III equipment. This equipment shall comply with the requirements of general industry standards.

GR-1.3 APPLICATIONS

This Standard applies to the design, manufacture, testing, inspection, shipment, storage, and erection of the cranes, monorails, hoists, and trolleys listed herein. This Standard provides guidance on how to identify the type of crane or monorail system configuration and the appropriate hoist and trolley configuration.

GR-1.4 RESPONSIBILITY

This Standard classifies equipment into three types, as noted in para. GR-1.2.1. The classification basis shall be the equipment location and usage at a nuclear facility.

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

Facilities other than nuclear may use this Standard either in part or in its entirety. Determining the extent to which this Standard is used is the responsibility of those referencing it.

Section GR-2 Environmental Conditions of Service

GR-2.1 GENERAL

The owner shall specify environmental conditions for equipment operation and storage so that the manufacturer can design the equipment to withstand the effects of those conditions.

Where the ability of the equipment to withstand the environmental conditions is limited or unknown, the manufacturer shall identify the limitations and lack of information. The manufacturer shall provide the basis for acceptance of the equipment in the specified environmental conditions.

GR-2.1.1 Clearances

The crane, monorail, hoist, or trolley design shall provide clearance between the equipment and the building and surrounding obstructions.

(a) Vertical Clearance. The clearance between the highest point of a moving crane or monorail component and the lowest overhead obstruction shall be at least 3 in. after taking into account variables that affect the elevation of the overhead structure relative to the equipment, including, but not limited to, external loads such as snow and wind.

(b) Horizontal Clearance. The clearance between the sides and ends of traveling cranes, jib booms, or hoist and trolley units and the building columns and other obstructions shall be at least 2 in. Measure the clearance with the crane centered on the runway rails and the hoist and trolley unit centered on the operating flange.

(c) Overall. The equipment 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.

GR-2.1.2 Hazardous Locations

Cranes, hoists, and trolleys installed in hazardous locations as defined by NFPA 70 (latest issue) or other special codes may require modifications or additional safety precautions not covered by this Standard. The design of cranes, hoists, and trolleys in hazardous locations shall meet the requirements for those locations.

GR-2.2 RADIATION

(a) The owner shall specify the expected accumulated radiation dosage exposure to the crane, hoist, monorail, or trolley over the life of the facility.

(b) The manufacturer shall identify components whose normal life could be reduced by the effects of the specified radiation. The manufacturer shall provide this list to the owner.

(c) For components whose failure due to exposure to the specified radiation could result in loss of load, the manufacturer shall

(1) design the components to withstand the specified radiation, or

(2) identify the replacement period for the components

(d) The manufacturer shall note where insufficient data are available to determine radiation effects on components and provide recommended inspection and replacement strategies to the owner for these components.

(e) The manufacturer shall specify and provide to the owner the inspection requirements for components affected by radiation.

GR-2.3 TEMPERATURE AND HUMIDITY

(a) The owner shall specify the following temperature requirements in the area where the crane, hoist, monorail, or trolley will operate:

(1) maximum operating temperature
(2) minimum operating temperature
(3) ambient temperature for motors
(4) maximum construction temperature
(5) minimum construction temperature
(6) humidity conditions

(b) The manufacturer shall design the crane, hoist, monorail, or trolley to withstand the effects of the specified temperatures and humidity or shall specify the limitations of the equipment's design concerning these conditions.

(c) The manufacturer shall specify the inspection requirements for components affected by temperature and humidity and shall provide this information to the owner.

GR-2.4 PRESSURE

(a) The owner shall specify the following pressure requirements in the area where the crane, hoist, monorail, or trolley will operate:

(1) normal operating pressure

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

(b) The manufacturer shall design the crane, hoist, monorail, or trolley to withstand the effects of the specified pressures or shall specify the limitations of the equipment's design concerning these pressure conditions.

(c) Where there are changes in pressure, the design shall include vented enclosures.

(d) The manufacturer shall specify the inspection requirements for components affected by pressure and shall provide this information to the owner.

GR-2.5 CHEMICALS

(a) Spray Systems

(1) Where cranes, hoists, or monorails are subject to spray systems, the owner shall specify the chemistry of the spray and any material restrictions of the hoist, crane, monorail, or trolley due to the effects of the spray.

(2) Where a corrosive spray is present, the possibility of hydrogen generation exists. The manufacturer shall minimize the use of exposed aluminum, magnesium, galvanized steel, and zinc. If these materials are used, the manufacturer shall provide the owner with a list of affected components, the amounts of the material used, and the location of each component.

(3) The manufacturer shall design the crane, hoist, monorail, or trolley to withstand the effects of the specified spray and shall not use the specified restricted materials. Before construction of the equipment, the manufacturer shall specify any limitations of the design concerning the spray condition and the use of any restricted materials.

(b) Liquid Immersion

(1) If the hoist load block and wire rope are to be immersed in a liquid, the owner should identify the immersion liquid and the manufacturer should select lubricants and component materials compatible with the immersion liquid. The manufacturer should address compatibilities between lubricants used in the manufacture of wire rope and the immersion liquid.

(2) Design requirements shall address liquid entrapment in components such as sealed bearings, load blocks, and the wire rope to prevent degradation of lubricants and to protect the components from corrosion.

(3) The manufacturer shall lubricate load blocks and wire ropes that are to be immersed in liquid with a lubricant that meets the specified lubrication requirements. The manufacturer shall specify any limitations of the equipment design concerning the water chemistry and lubrication requirements.

(c) Inspection and Maintenance Considerations. The manufacturer shall specify the inspection and maintenance requirements, including the bases for these requirements, for components that may be affected by the owner-specified chemicals (spray systems or liquid immersion) and provide this information to the owner.

GR-2.6 WIND

The manufacturer shall design the crane, hoist, monorail, or trolley to operate under any specified operating wind conditions.

The manufacturer shall design the crane, hoist, monorail, or trolley to withstand the effects of specified stored wind conditions or tornado wind conditions while stowed.

GR-2.7 SEISMIC CONDITIONS

(a) The owner shall specify the SSE parameters for Type I and Type II equipment.

(b) The manufacturer shall design Type I and Type II equipment to withstand the effects of the seismic conditions specified in Parts CM and HT.

GR-2.8 DRAINAGE

When required by environmental conditions, box sections shall include drain holes 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 include drain holes. The design shall include holes provided in the bottom flange of the box girder for draining each compartment formed by the diaphragms within the whole box girder.

Section GR-3
Performance Requirements

GR-3.1 GENERAL

(a) This Section addresses performance requirements for Type I and Type II equipment. The owner may supplement these requirements to define special performance requirements for a specific nuclear facility.

(b) The owner shall specify the service class, capacity, speeds, and dimensions required of the Type I and Type II equipment.

GR-3.2 SERVICE CLASS

The owner shall specify the crane, monorail, or hoist service class necessary to meet the application. The owner shall state any specific requirements deviating from the selected service class description.

GR-3.2.1 Crane and Monorail Service Class

Table GR-3.2.1-1 lists the service classes for cranes and monorails excluding the hoist and hoists with integral trolley.

GR-3.2.2 Electrically Operated Hoist Service Class

Table GR-3.2.2-1 lists the service classes for electric hoists.

GR-3.2.3 Air-Operated Hoist Service Class

Table GR-3.2.3-1 lists the service classes for air-operated, air-powered hoists.

GR-3.3 EQUIPMENT CAPACITY

(a) Equipment capacity is the maximum rated load that the equipment handles. The owner shall specify the equipment capacity.

(b) If more than one trolley hoist will or may operate on a crane bridge or monorail, the owner shall specify the crane bridge or monorail that will handle the most severe loading conditions.

GR-3.4 OPERATIONAL CHARACTERISTICS

GR-3.4.1 Speeds

The owner shall specify the operational speeds of the crane, trolley, and electric- and air-operated hoists. These speeds depend on the nature of the load, load clearances, weight of load, position of the operator, load positioning accuracy, and type of drive. The selected speeds shall allow for controlled handling of the equipment and the load.

(a) Table GR-3.4.1-1 provides suggested maximum operating speeds for electric wire rope hoists.

(b) Table GR-3.4.1-2 provides suggested maximum speeds for air hoists.

(c) Table GR-3.4.1-3 provides suggested operating speeds for crane bridges and trolleys.

(d) Table GR-3.4.1-4 provides suggested operating speeds for electric chain hoists.

(e) The suggested maximum jib rotation speed is 0.5 rpm to 1.0 rpm.

GR-3.4.2 Hoist Hand-Chain Pull and Overhaul Characteristics

Table GR-3.4.2-1 provides the typical hoist hand-chain pull and overhaul characteristics. The owner shall verify that the characteristics for the selected hoist are suitable for the application

GR-3.5 VERTICAL LIFT CONSIDERATIONS

The owner shall determine and specify whether true vertical lift is required.

Table GR-3.2.1-1
Service Classes for Cranes and Monorails

		Service Conditions			
Class	Service Class	Lift Frequency/hr	Average Lift Height, ft	Average Load Capacity	Typical Operating Conditions
A	Infrequent or standby	1 or fewer	Full Range	No restriction	Precision handling at slow speed; long idle periods
B	Light	2–5	10	No restriction	Generally slow operation
C	Moderate	5–10	15	Not more than 50%	No more than half the lifts at rated capacity
D	Heavy	10–20	15	50%–75%	General fast operation; no more than 65% at rated capacity
E	Severe	20 or more	No restriction	75%–90%	
F	Continuous severe	20 or more	No restriction	No restriction	Service conditions are severe; may include custom-designed specialty cranes for critical tasks

Table GR-3.2.2-1
Service Classes for Electrically Operated Hoists

		Operational Time Ratings at k = 0.65 [Note (1)]			
		Uniformly Distributed Work Periods		Infrequent Work Periods	
Class	Service Conditions	Maximum On Time, min (% hr)	Maximum Number of Starts/hr	Maximum On Time, Cold Start, min	Maximum Number of Starts/hr
H1	Construction and maintenance use; frequent rated load; idle for 1–6 months between periods of operation	7.5 (12.5)	75	15	100
H2	Random load distribution; rated loads infrequent	7.5 (12.5)	75	15	100
H3	Random load distribution	15 (25)	150	30	200
H4	High volume of heavy loads; manual or automatic cycling of lighter loads; infrequent near-capacity loads	30 (50)	300	30	300
H5	Approaches continuous operations; user shall specify exact details of operation, including weight of attachments	60 (100)	600	N/A [Note (2)]	N/A [Note (2)]

NOTES:
(1) k = mean effective load factor.
(2) N/A = not applicable since there are no infrequent work periods in Class H5 service.

Table GR-3.2.3-1
Service Classes for Air-Operated Wire Rope and Chain Hoists

Class	Service Conditions
A4	<50% rated load up to continuous runtime OR >50% rated load up to 50% runtime
A5	Typically >50% rated load with >50% runtime

Table GR-3.4.1-1
Recommended Electric Wire Rope Hoist Speeds

Rated Load, ton [Note (1)]	Hoist Duty Class and Hoist Speed, ft/min		
	H1 and H2	H3	H4
<3	10–15	12–30	25–50
3–5	10–15	12–30	20–40
>5–7.5	10–15	12–25	15–30
>7.5–10	7–10	10–20	15–30
>10–15	7–10	10–15	10–20
>15–20	5–10	10–15	10–15
>20–30	5–10	8–15	10–15
>30–40	4–8	6–12	6–12
>40	4–8	5–10	5–10

GENERAL NOTES:
(a) For class H5 units, speeds can be determined only after the quantity of material to be handled and the time allotted to complete the work have been established.
(b) For trolleys of an I-beam hoist unit, it is recommended to use a trolley in Table GR-3.4.1-3, where hoist classes H1, H2, H3, H4, and H5 are basically equivalent to the crane and monorail classes, A, B, C, D, and E.

NOTE: (1) Ton = 2,000 lb.

Table GR-3.4.1-2
Recommended Air Hoist Speeds

Rated Load, ton [Note (1)]	Wire Rope, ft/min	Chain, ft/min
<3	20	19
3–5	18	10
>5–10	18	5
>10–20	10	4

NOTE: (1) Ton = 2,000 lb.

Table GR-3.4.1-3
Recommended Crane Bridge and Trolley Speeds

Rated Load, ton [Note (1)]	Bridge and Trolley Speed, ft/min		
	Classes A and B	Class C	Class D
0–10	10–15	12–30	25–50
>10–20	10–15	12–30	20–40
>20–50	4–8	5–10	5–10

GENERAL NOTE: For Class E units, speeds can be determined only after the quantity of material to be handled and the time allotted to complete the work have been established.

NOTE: (1) Ton = 2,000 lb.

Table GR-3.4.1-4
Recommended Electric Chain Hoist Speeds

Rated Load, ton [Note (1)]	Chain, ft/min
1/8	16–64
1/4 to 1	7–64
1 1/2 to 3	4–40
>3	4–24

NOTE: (1) Ton = 2,000 lb.

Table GR-3.4.2-1
Typical Hoist Hand-Chain Pull and Overhaul Characteristics

Rated Load, ton [Note (1)]	Hand-Chain Pull Force [Note (2)], lb		Hand-Chain Overhaul to Lift Load 1 ft [Note (3)], lb	
	Separate From Trolley	Integral With Trolley	Separate From Trolley	Integral With Trolley
Up to 0.25	15–50	15–25	10–50	25–25
>0.25 to 0.5	20–65	25–50	15–60	20–60
>0.5 to 1	45–85	45–70	25–60	30–55
>1 to 1.50	40–105	40–80	35–90	40–85
>1.5 to 2	55–115	55–95	40–80	50–85
>2 to 3	40–110	40–85	65–180	60–175
>3 to 4	55–140	55–95	70–180	100–175
>4 to 5	45–105	50–80	125–260	155–250
>5 to 6	55–140	60–95	125–260	155–250
>6 to 8	45–165	45–90	130–500	220–500
>8 to 10	55–135	55–100	210–500	255–500
>10 to 12	60–175	65–105	105–500	175–500
>12 to 16	70–180	65–95	230–710	230–710
>16 to 20	70–190	89–90	290–770	290–760
>20 to 24	100–205	100–110	350–770	350–760
>24 to 25	90–165	...	345–420	...
>25 to 30	90–120	...	380–510	...
>30 to 40	85–135	...	460–770	...
>40	110–135	...	460–770	...

GENERAL NOTE: This table indicates the characteristics of hoists generally available. Those values including a dash (e.g., 15–50) denote typical ranges.

NOTES:
(1) Ton = 2,000 lb.
(2) Standard lifts are 8 ft, 0 in. Weights are predicated on standard lifts. Other lifts are available. The corresponding hand-chain drop is normally 2 ft, 0 in. less than the reach.
(3) Values refer to each hand chain when two or more hand chains are required.

Section GR-4
Coatings and Finishes

GR-4.1 COATING SERVICE LEVELS

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

(a) Coating service Level I is 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 is 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 facilitate decontamination in those areas outside primary containment subject to radiation exposure and radionuclide contamination. Coating service Level II also applies to coatings in non-radiation areas.

GR-4.2 SPECIFIC REQUIREMENTS FOR COATING SERVICE LEVELS

GR-4.2.1 Requirements for Coating Service Level I

(a) Coating requirements for coating service Level I shall be in accordance with ASTM D5144, which requires a quality assurance program.

(b) Inspection and testing of coatings for coating service Level I shall be in accordance with ASTM D5144.

(c) The owner shall specify specific coating inspections dependent upon the coating system used. Refer to ASTM D5161 for selecting and specifying appropriate inspection requirements.

GR-4.2.2 Requirements for Coating Service Level II

(a) The owner shall specify coating requirements for coating service Level II. 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 only apply as specified by the owner.

GR-4.2.3 Additional Requirements Applicable to All Coatings

The following paragraphs describe additional requirements for coatings and finishes:

(a) If not specified by the owner, the manufacturer shall determine the type of coating 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

(1) the coating system is specifically designed and formulated as a weldable system, and

(2) the coating manufacturer provides documentation to attest to this capability

The owner shall approve the use of these coatings.

(c) Before assembly, the manufacturer shall coat surfaces exposed to the environment that will be inaccessible after assembly, such as wheel wells and hubs.

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

(e) The manufacturer shall not apply the specified coating system to friction-type joints joined by high-strength bolts. The manufacturer may coat these surfaces with organic or inorganic zinc coating systems not prohibited by subsection GR-2.5.

(f) For shipping and storage, the manufacturer shall protect 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) with an appropriate preservative.

(1) The manufacturer shall specify which preservatives the owner must remove for proper operation of the equipment.

(2) The owner may remove other preservatives after installation of the equipment.

(g) The manufacturer shall not force-cure or force-dry the coating system unless recommended by the coating manufacturer.

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

(i) The manufacturer may furnish finished components with conventional coatings unless otherwise specified by the owner. Examples of such finished components include 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.

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

(k) The manufacturer shall prevent all labels and nameplates affixed to components from being obscured during the coating process.

(l) The manufacturer shall supply items such as fasteners and conduits with the specified coating system, either galvanized or plated. Galvanizing or plating shall be subject to the requirements of subsection GR-2.5. When specifically requested by the owner, the manufacturer shall provide a list of galvanized or plated parts.

(m) The manufacturer shall remove surface contaminants such as grease and oil detected after blasting to produce the surface conditions required by the appropriate Steel Structures Painting Council (SSPC) surface preparation.

(1) If there is visible deterioration of the surface beyond the specified SSPC preparation, the manufacturer shall prepare the surface again.

(2) The manufacturer shall prepare surfaces using the original preparation methods, except in small areas requiring repair or touch up in which conventional blasting is not desirable. These areas may be prepared the second time by one of the following methods, listed in descending order of effectiveness:

(-a) Vacuum blast to clean an abrasive finish with a minimum 2.0 mm profile. The minimum blasting air pressure shall be 50 psi at the blasting nozzle.

(-b) Clean the surface using a grinding wheel, sanding disk, or other device to provide a minimum 2.0 mm profile in accordance with SSPC SP-3. The manufacturer should use a needle gun to roughen the surface after grinding.

(-c) Hand-sand or wire-brush the surface to obtain as clean a surface as possible in accordance with SSPC SP-2.

Section GR-5
Quality Assurance

GR-5.1 REQUIREMENTS

GR-5.1.1 Type I Equipment

(a) The quality assurance program of the manufacturer of Type I equipment shall meet ASME NQA-1 or shall meet the quality assurance requirements specified by the owner.

(b) The owner may require quality assurance measures from suppliers of structural, mechanical, and electrical components used on Type I equipment in addition to those listed in Table CM-2.1.5.1-2 and the applicable table of Part HT, as noted below.

(1) Table HT-2.9.1-1 for Type IA powered wire rope hoists

(2) Table HT-3.8.1-1 for Type IB powered wire rope hoists

(3) Table HT-4.8.1-1 for Type IB powered chain hoists

(4) Table HT-5.6.1-1 for Type IB hand-chain hoists

(5) Table HT-6.6.1-1 for Type IB independent or integral under-running trolleys

GR-5.1.2 Type II Equipment

(a) The quality assurance program of the manufacturer of Type II equipment shall meet ASME NQA-1 or shall meet the quality assurance requirements specified by the owner.

(b) The owner may require quality assurance measures from suppliers of structural components used on Type II cranes and monorails in addition to those listed in Table CM-2.1.5.1-2.

(c) The owner may also require quality assurance measures from suppliers of electrical and mechanical components used on Type II equipment.

GR-5.2 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. The owner's quality assurance program shall define which of these quality assurance documents are permanent records.

Paragraph GR-5.2.2 provides additional recommendations for quality documentation the owner may require.

As a minimum, the following documentation shall be included in the owner's purchase documents for all cranes:

(a) *Design and Manufacturing Documentation*

(1) assembly and outline drawings

(2) electrical schematics and wiring diagrams

(3) system calculations (mechanical, electrical, structural)

(4) acceptance test plans and procedures

(5) software test plans for controls

(6) operating instructions

(7) maintenance instructions

(8) software programs

(b) *Installation Documentation*

(1) records of high-strength bolt torquing

(2) data sheets or logs on equipment installation, inspection, and alignment

(3) lubrication records

(4) documentation of testing performed after installation and prior to equipment acceptance

(5) results of end-to-end electrical tests

(6) final system adjustment data

(7) acceptance test plan, procedures, and results

(8) load test

(9) load summary reports

GR-5.2.1 Recommendation for the Manufacturer

The manufacturer should establish a system for the collection and temporary storage of records received and generated during the design, manufacture, and shipment of the equipment. The manufacturer should submit these records to the owner or to the owner's designated representative.

GR-5.2.2 Recommendation for Additional Records Submitted to the Owner for Design and Manufacture

In addition to the minimum documentation listed in subsection GR-5.2, the owner may request the following additional records from the manufacturer:

(a) as-built drawings, including a complete list of equipment and material.

(b) suppler deviation requests and approvals.

(c) shop no-load test report for the crane or hoist.
(d) software test plans for controls.
(e) control logic diagrams.
(f) hard copy and soft copy with license of installed programmable logic controller (PLC) software and programs.
(g) National Electrical Manufacturers Association (NEMA) routine test reports for hoist motors.
(h) material test reports per Tables CM-2.1.5.1-2, HT-2.9.1-1, HT-3.8.1-1, HT-4.8.1-1, HT-5.6.1-1, and HT-6.6.1-1.
(i) nondestructive examination (NDE) reports per Tables CM-2.1.5.1-2, HT-2.9.1-1, HT-3.8.1-1, HT-4.8.1-1, HT-5.6.1-1, and HT-6.6.1-1.
(j) radiographic film per tables per Tables CM-2.1.5.1-2, HT-2.9.1-1, HT-3.8.1-1, HT-4.8.1-1, HT-5.6.1-1, and HT-6.6.1-1.
(k) certificates of conformance per Table CM-2.1.5.1-1.
(l) welding procedures and welder certificates.
(m) weld filler material certificates of conformance, including heat or lot numbers.
(n) fastener material for structural connection material test reports.
(o) breaking strength report for each hoist wire rope.
(p) breaking strength report for each hoist load chain.
(q) hook load test reports.
(r) operating instructions outlining the step-by-step procedures for system start-up, operation, and shutdown. Instructions should include a brief description of all equipment and its basic operating features and control philosophy.
(s) maintenance instructions listing procedures, possible breakdowns, repairs, and troubleshooting guides.
(t) training manuals for operations and maintenance.

GR-5.2.3 Recommendation When Using an Intermediate Storage Facility

The owner may specify that an intermediate storage facility establishes a system for the collection, storage, and submittal of quality assurance records to the owner in accordance with ASME NQA-1.

GR-5.2.4 Recommendation for the Constructor and Erector

The owner may specify that the constructor organization and erector organization establish a system for the collection, storage, and submittal of quality assurance records to the owner. The owner may specify submittal of the following 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
(h) welding filler material reports, including heat and lot numbers
(i) welding material control procedures
(j) welder qualification
(k) data sheets or logs on equipment installation, inspection, and alignment
(l) erection procedures
(m) lubrication records
(n) documentation of testing performed after installation and prior to equipment acceptance
(o) results of end-to-end electrical tests
(p) instrument calibration results, including test equipment
(q) as-built drawings approved by the owner
(r) field audit reports
(s) field quality assurance manuals and daily reports
(t) final inspection reports
(u) nonconformance reports
(v) final system adjustment data
(w) acceptance test procedures and results
(x) load test

Section GR-6
Definitions

GR-6.1 DEFINITIONS

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

auxiliary girder: a girder arranged parallel to the main girder for supporting the platform motor base, operator's cab, control panels, etc., to reduce the torsional forces such load would otherwise impose on the main girder.

block, load: the assembly of hook or shackle, swivel, bearing, sheaves, sprockets, pins, and frame suspended by the hoist rope or load chain. This shall include any appurtenances reeved in the hoisting rope or load chain.

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

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

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 or hand-chain wheel to lower a load but does not impose any additional load on the motor or hand-chain wheel when lifting a load. This may also be used as a holding brake if designed as such by the manufacturer.

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

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

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

braking torque: torque on a drive system created by the application of a brake and dynamic motor braking.

camber: the slight upward vertical curve given to bridge and runway girders to compensate partially for deflection due to hook load and weight of the crane.

capacity, rated: see *load, rated*.

carrier: a unit that travels on the bottom flange of a monorail track, jib boom, or bridge girder to transport a load. Also called *trolley*.

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

chain, hand: the chain grasped by a person to apply force required for lifting or lowering motion.

chain, load: the load-bearing chain in a hoist.

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

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

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, by power, or a combination of both.

crane, gantry: a crane similar to an overhead crane that rigidly supports the bridge that carries the trolley on two or more legs running on fixed rails or other runway.

crane, jib: a fixed crane, usually mounted on a wall or building column, consisting of a rotating horizontal boom (either cantilevered or supported by tie rods) carrying a trolley or hoist.

crane, jib, free-standing pillar: a jib crane that may be base-mounted or insert-mounted. The jib boom may be fixed or have partial or full 360-deg rotation (specified degree of overlap or continuous) and can be manually or power operated (see Figure GR-6.2.4-2).

crane, jib, mast-type: a jib crane that may be top-braced, under-braced, or fully cantilevered. The jib boom may be fixed or have partial or full 360-deg rotation (specified degree of overlap or continuous) and can be manually or power operated (see Figure GR-6.2.4-3).

crane, jib, wall-mounted: a jib crane that may be top-braced, under-braced, or full cantilever type. The jib boom may be fixed or have partial rotation; can be manually or power operated; and may be a patented shape, a structural shape, a reinforced patented or structural shape, or a fabricated section (see Figure GR-6.2.4-1).

crane, top-running, double-girder with top-running trolley: a crane that has end trucks that operate on fixed rails or tracks attached to the top flange or surface of runway girders and that uses a trolley hoist unit or units that operate on fixed rails or tracks attached to the top flange or surface of the bridge girders. See ASME NOG-1 for requirements.

crane, top-running, double-girder with underhung trolley: a crane that has end trucks that operate on fixed rails or tracks attached to the top flange or surface of runway girders, and that uses an underhung, trolley-suspended hoist. Overhead hoists of the underhung type may be rigidly suspended or trolley-suspended from the bridge girders. The trolley operates on the bottom flange of the bridge girders, which may be a patented shape, a structural shape, a reinforced patented or structural shape, or a fabricated section (see Figure GR-6.2.2-2).

crane, top-running, single-girder: a crane with end trucks that operate on fixed rails or tracks attached to the top flange or surface of runway girders (see Figure GR-6.2.2-1).

crane, top-running, single-girder, gantry: a crane with both ends of the bridge rigidly supported on legs, with the legs supported on end trucks operating on fixed rails or tracks (see Figure GR-6.2.2-4).

crane, top-running, single-girder, semi-gantry: a crane with one end of the bridge supported by an end truck operating on a fixed rail or track attached to the top flange or surface of a runway girder. The other end of the bridge is rigidly supported on a leg, with the leg supported on an end truck operating on a fixed rail or track at a different level (see Figure GR-6.2.2-3).

crane, traveling wall: a crane with a vertical frame supported on trucks that operate on tracks or rails by manual or powered operation. It also has a jib boom that can be single or multiple girder; top-braced, under-braced, or full cantilever; and is usually fixed (non-rotating) to the vertical frame. The jib may be a patented shape, a structural shape, a reinforced patented or structural shape, or a fabricated section (see Figure GR-6.2.3-1).

crane, underhung: a crane with a single- or multiple-girder movable bridge carrying a movable or fixed hoisting mechanism and traveling on the lower flanges of an overhead runway (see Figures GR-6.2.1-1 through GR-6.2.1-3).

crane, underhung, semi-gantry: a crane with one end of the bridge supported by wheels operating on the bottom flange of a runway track and the other end of the bridge rigidly supported on a leg, with the leg supported on a top running end truck operating on a fixed rail or track (see Figure GR-6.2.1-4).

cross shaft: the shaft extending across the bridge, used to transmit torque from motor to bridge drive wheels.

deflection: displacement due to bending or twisting in a vertical or lateral plane caused by the imposed live and dead loads.

drop section: a mechanism that permits a section of track or tracks to be lifted or lowered out of alignment with the stationary track or tracks. Also called *lift section*.

drum: a cylindrical member around which rope is wound for lifting or lowering the load.

electric baffle: conductors wired to cut off electric power to approaching motor-driven equipment if track switches, drop sections, and other movable track devices are not properly set for passage of equipment.

end stop: a device located at the end of the track to prevent the carrier from running off the end of the track.

end truck: an assembly consisting of the frame and wheels that supports the crane girder or girders and allows movement along the runway.

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

fork: a mechanical device for use on interlocking transfer equipment to mechanically prevent passage of a trolley or carrier when the elements are not securely locked.

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

girder: the principal horizontal beam of the crane bridge supporting the trolley that is supported by end trucks.

hand-chain drop: the distance to the lowest point of the hand chain measured from a known reference.

hand-chain overhaul: the number of feet the hand chain must travel to raise the load hook 1 ft.

hand-chain pull: the average force measured in pounds exerted by the operator on the hoist hand chain to lift the rated load.

hanger rod: steel rods that are used together with other fittings to suspend the track from the supporting structure.

hazardous locations: locations where fire or explosion hazards may exist. Locations are classified depending on the properties of the flammable vapors, liquids, gases, or combustible dusts or fibers present and the likelihood that a flammable or combustible concentration or quantity is present (see NFPA 70).

headroom: the distance measured with the load hook at its upper limit of travel from the saddle of the load hook to the position listed in (a) through (e) as appropriate.

(a) saddle of the top hook for hook-suspended hoists

(b) centerline of the suspension holes for lug-suspended hoists

(c) bottom of the beam for trolley-suspended hoists

(d) supporting surface for base-mounted and deck-mounted hoists

(e) uppermost point of hoist for wall-mounted and ceiling-mounted hoists

hoist: a machinery unit that is used for lifting or lowering a freely suspended (unguided) load.

hoist, air-operated chain: an air-powered hoist using chain as the lifting medium (see Figure GR-6.2.7-5).

hoist, air-operated wire rope: an air-powered hoist using wire rope as the lifting medium (see Figure GR-6.2.7-4).

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

hoist, electric chain: an electric-powered hoist using chain as the lifting medium (see Figure GR-6.2.7-3).

hoist, electric wire rope: an electric-powered hoist using wire rope as the lifting medium (see Figure GR-6.2.7-1).

hoist, hand-chain: a suspended machinery unit used for lifting or lowering a freely suspended (unguided) load by use of a hand-chain manual operation (see Figure GR-6.2.7-2).

hoist, underhung: trolley hoists or hoists suspended from trolleys traveling on the lower flanges of beams or similar hoists that are hook- or lug-suspended.

hook approach: the minimum horizontal distance between the center of the runway rail and the hook.

hook latch: a mechanical device to close (bridge) the throat opening of a hook.

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

interlocking mechanism: a mechanical device to lock together the adjacent ends of two cranes or a crane to a fixed transfer section or spur track to permit the transfer of carriers from one crane or track to the other.

L10 bearing life: the minimum expected life, in hours, of 90% of a group of bearings that are operated at a given speed and loading.

lift: the maximum safe vertical distance through which the hook, magnet, or bucket can move between its upper and lower limits of travel.

lift section: see *drop section.*

lift, true vertical: lift in which the load hook travels in a vertical path with no horizontal displacement between the lower limit of lift and the upper limit of lift.

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

load-carrying part: any part of the equipment for which the load on the hook influences induced stress.

load chain: the load suspension chain in the hoist consisting of a series of interwoven links that are formed and welded.

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. 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 owner shall specify the credible critical load.

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 owner.

load, dead (DL): the weight of all effective parts of the bridge structure, machinery parts, and fixed equipment supported by the structure.

load hang-up: the event in which the load block or the load, or both, stops during hoisting or traversing due to snagging or entanglement with heavy or fixed objects, creating a sudden and potentially severe overload.

load hook: the hook used to connect the load to the hoist.

load, lifted: the combination of the weight of the load and the lifting devices used for handling and holding the load, such as the load block, lifting beam, bucket, magnet, grab, and other supplemental devices.

load, live: a load that moves relative to the structure under consideration.

load, rated: the maximum load designated by the manufacturer or qualified person for which the equipment is designed and built. Also called *rated capacity*.

load, seismic lifted: the maximum lifted load under the evaluated seismic conditions where the crane or monorail structure and hoist and trolley unit must remain in place. This lifted load is not a critical load; therefore, retaining the load itself is not required during the seismic event.

load, trolley: the weight of the trolley and the equipment attached to the trolley.

load, wheel: the load, without impact, on any wheel with the trolley and lifted load (rated capacity) positioned on the bridge to give maximum loading.

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

monorail: a single run of overhead track on which trolleys travel, including curves, switches, transfer devices, and lift and drop sections.

monorail system: a machine for lifting and lowering a load and moving it horizontally, suspended from a single track (see Figures GR-6.2.5-1 through GR-6.2.5-6).

non-coasting mechanical drive: a drive that results in decelerating a trolley or bridge when power is not available. The braking effort will be established automatically when power to the drive is interrupted.

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

normal walking speed: a walking speed assumed to be 150 ft/min.

overload: any load greater than the rated load.

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

parts: number of lines of hoisting rope or chain supporting the load block or hook. Also called *lines.*

push-button station: an electrical control device consisting of push-button-operated contacts in an enclosure used by the operator to control the powered motions of the crane, carrier, hoist, and other auxiliary equipment.

qualified person: a person who, by possession of a recognized degree in an applicable field 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 and work.

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

rail sweep: a device attached to the crane and located in front of the crane's leading wheels to push aside loose obstructions.

reach: the distance from the saddle of the load hook at its lower limit of lift to the upper point of the headroom measurement. Reach is equal to lift plus headroom.

reeving: a system in which a rope or chain travels around drums, sheaves, or sprockets.

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

runway conductors: the main conductors mounted on or parallel to the runway that supply current to the crane.

safety lug: a mechanical device fixed securely to the end truck or trolley yoke that limits the fall of the crane or carrier in case of wheel or axle failure.

shall: a word indicating a requirement.

sheave: a wheel or pulley used with a rope or chain to change direction and point of application of a pulling force.

sheave, running: a sheave that rotates as the load block raises or lowers.

should: a word indicating a recommendation.

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.

slew drive: the mechanism (including motor and gearing) used to rotate a jib boom about a vertical axis.

span: the horizontal distance, center-to-center, between runway rails.

sprocket, load: a hoist component that transmits motion to the load chain. Other names for this component are *load wheel, load sheave*, *pocket wheel*, or *chain wheel*.

static control: a method of switching electrical circuits without the use of contacts.

switch: a device for making, breaking, or changing connections in an electric or pneumatic circuit (valve).

switch, cross-track: a track switch containing one straight section of track, pivoted at the center, that can be rotated to align it with other crossing tracks to allow passage of the carrier through the junction without changing the direction of the carrier motion.

switch, track: a device with a moving section of track that can be moved to permit passage of a carrier from one incoming fixed track to one outgoing fixed track.

track opener: a section of monorail track arranged to lift or swing out of line to make an opening through which a door may pass.

tractor drive: a motor-driven unit supported by wheels and propelled by drive wheel or wheels bearing on the underside of the track.

trolley: the unit carrying the hoisting mechanism that travels on the bridge rails or bottom flange of a monorail track or bridge girder to transport the load.

trolley: the unit that travels on the lower or upper flange of the bridge girder and carries the hoist. Also called *carrier.*

trolley, underrunning: a trolley that is suspended from the underside of one or more girders; it may be integral to a hoist or furnished as a separate unit to which a hoist or load could be attached.

truck: a 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 a sudden and potentially severe overload.

Type I equipment: a crane, monorail, or hoist used to handle a critical load. The design and construction of Type I equipment is such 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. The design of Type I equipment shall include either single failure-proof features (Type IA) or enhanced safety features (Type IB).

Type IA equipment: a Type I crane, monorail, or hoist that includes single failure-proof features so that any credible failure of a single component will not result in the loss of capability to stop and hold the critical load.

Type IB equipment: a Type I crane, monorail, or hoist with enhanced safety features, including increased design factors and redundant components that minimize the potential for failure that would result in the loss of capability to stop and hold the critical load.

Type II equipment: a crane, hoist, or monorail not used to handle a critical load. The design and construction of Type II equipment is such that it will remain in place 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.

Type III equipment: a crane, hoist, or monorail not used to handle a critical load; no seismic considerations are necessary, and no single failure-proof features are required.

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.

GR-6.2 FIGURES OF CRANES

GR-6.2.1 Underhung Cranes

Underhung cranes may be single or multiple girder.

(a) underhung single-girder crane (see Figure GR-6.2.1-1)

(b) underhung multiple-girder crane (see Figures GR-6.2.1-2 and GR-6.2.1-3)

(c) underhung semi-gantry crane (see Figure GR-6.2.1-4)

GR-6.2.2 Top-Running Cranes

Top-running cranes have overhead hoists of the underhung type that may be rigidly suspended or trolley-suspended from the bridge girders. The trolley operates on the bottom flange of the bridge girders, which may be a patented shape, structural shape, reinforced patented or structural shape, or fabricated section.

(a) top-running single-girder crane (see Figure GR-6.2.2-1)

(b) top-running double-girder crane (see Figure GR-6.2.2-2)

(c) top-running single-girder semi-gantry crane (see Figure GR-6.2.2-3)

(d) top-running single-girder gantry crane (see Figure GR-6.2.2-4)

GR-6.2.3 Traveling Wall Cranes

Traveling wall cranes may have single- or multiple-girder booms.

On single-girder booms, overhead hoists of the underhung type may be rigidly suspended or trolley-suspended from the jib boom. If the trolley is suspended, the trolley will operate on the bottom flange of the jib boom.

On multiple-girder booms, overhead hoists of the underhung type may be rigidly suspended or trolley-suspended from the jib boom girders. If the trolley is suspended, the trolley may operate on the bottom flange of the boom girders or on fixed rails or track attached to the top flange or surface of the boom girders (see Figure GR-6.2.3-1).

GR-6.2.4 Jib Cranes

Jib cranes may have overhead hoists of the underhung type that may be rigidly suspended or trolley-suspended from the jib boom. If trolley-suspended, the trolley will operate on the bottom flange of the jib boom.

(a) wall-mounted jib cranes (see Figure GR-6.2.4-1)

(b) freestanding pillar jib cranes (see Figure GR-6.2.4-2)

(c) mast-type jib cranes (see Figure GR-6.2.4-3)

GR-6.2.5 Monorail Systems

Monorail systems incorporate single-track monorails and include curves, switches, transfer devices, lift and drop sections, and associated equipment (see Figures GR-6.2.5-1 through GR-6.2.5-6). Equipment installed on these monorails may be manually operated, power-operated, or operate automatically. Operation may be controlled from the floor, a cab, a pulpit, or remotely. For monorail systems, the trolley operates on the bottom flange of the track. The monorail track may be a patented shape, structural shape, reinforced patented or structural shape, or fabricated section.

GR-6.2.6 Under-Running Trolleys

Under-running trolleys may be suspended from multiple girders or a single girder. Trolleys may be either integral with a hoist or furnished as separate units to which a hoist or load could be attached (see Figure GR-6.2.6-1).

(a) plain (push) type

(b) hand-chain-operated

(c) motor-operated

GR-6.2.7 Overhead Hoists

Overhead hoists fall into one of the following five categories:

(a) electric wire rope hoist (see Figure GR-6.2.7-1)
(b) hand-chain hoist (see Figure GR-6.2.7-2)
(c) electric chain hoist (see Figure GR-6.2.7-3)
(d) air-operated wire rope hoist (see Figure GR-6.2.7-4)
(e) air-operated chain hoist (see Figure GR-6.2.7-5)

GR-6.2.7.1 Hoist Suspension Types. Hoists suspension varies based on the type of hoist and application. The suspension types listed below are typical for the application listed.

(a) Both electric- and air-operated wire rope hoists use one of the following suspension types. See Figure GR-6.2.7.1-1.

(1) lug
(2) hook
(3) trolley
(4) base- or deck-mounted
(5) wall-mounted
(6) ceiling-mounted

(b) Hand-chain hoists use one of the following suspension types. See Figure GR-6.2.7.1-2.

(1) clevis
(2) hook
(3) trolley

(c) Both electric- and air-operated chain hoists use one of the following suspension types. See Figure GR-6.2.7.1-3.

(1) hook or clevis
(2) lug
(3) trolley

Figure GR-6.2.1-1
Underhung Single-Girder Crane

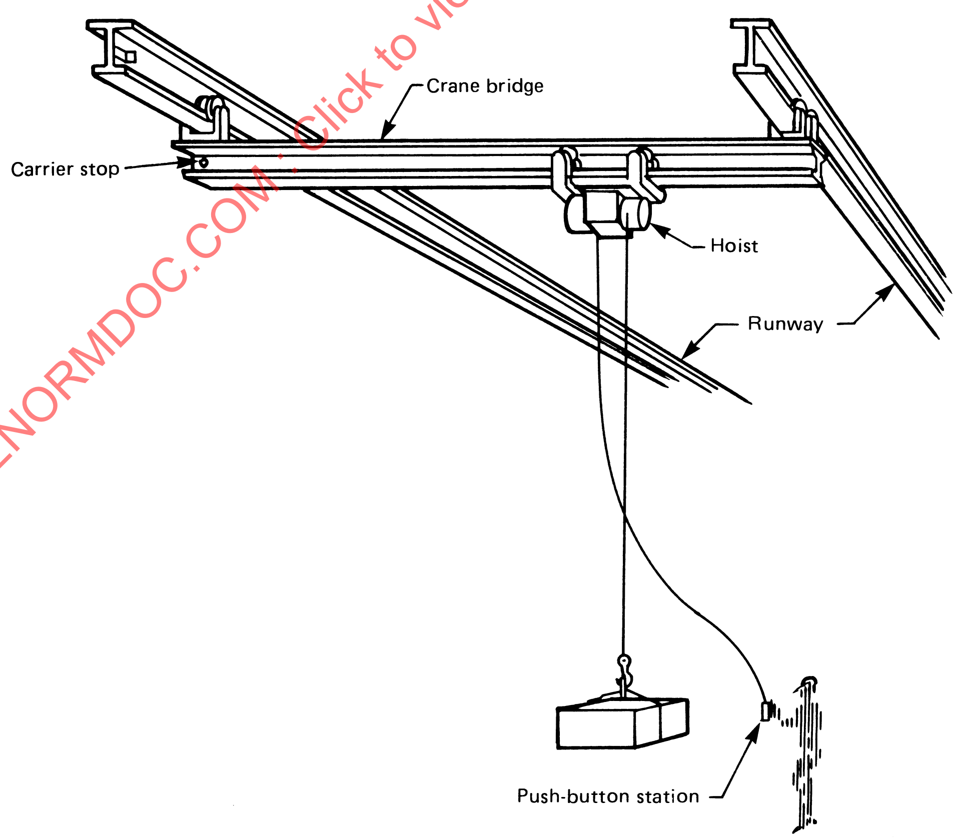


Figure GR-6.2.1-2
Underhung Double-Girder Crane With Underhung Trolley

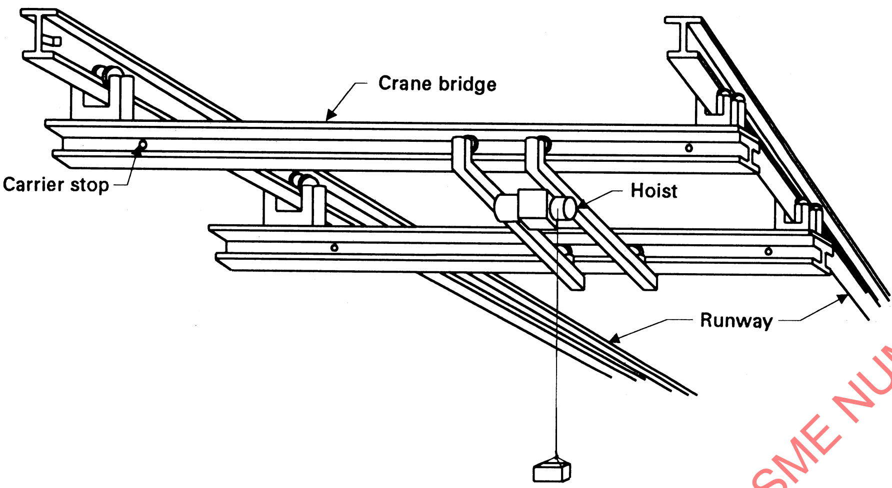


Figure GR-6.2.1-3
Underhung Double-Girder Crane With Top-Running Trolley

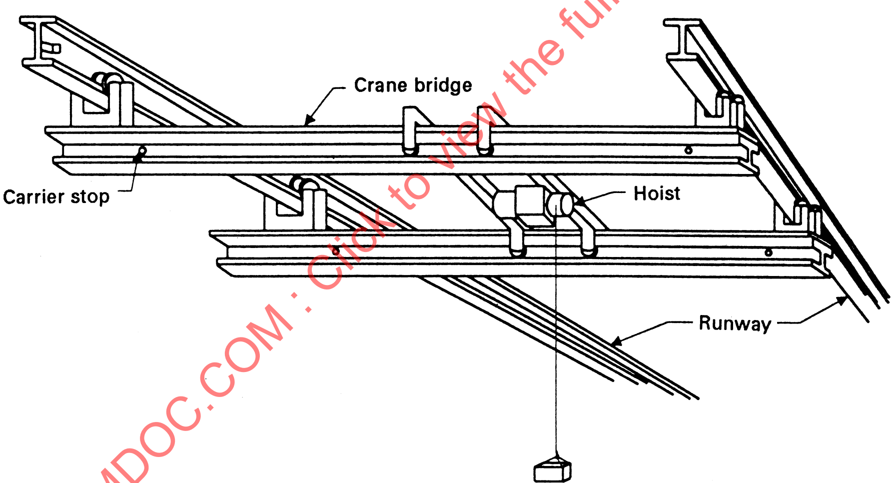


Figure GR-6.2.1-4
Underhung Single-Girder Semi-Gantry Crane

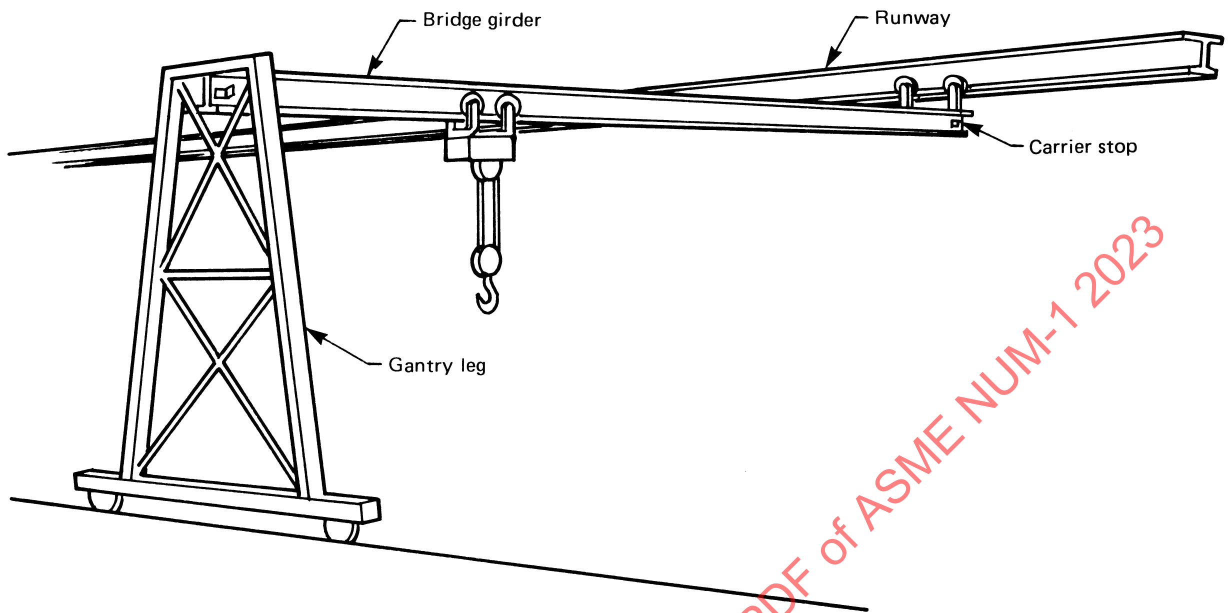


Figure GR-6.2.2-1
Top-Running Single-Girder Crane

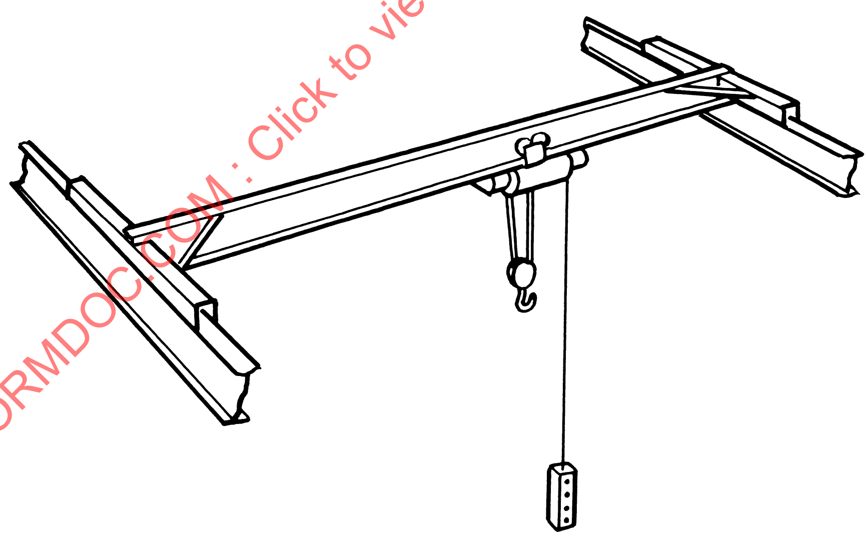


Figure GR-6.2.2-2
Top-Running Double-Girder Crane

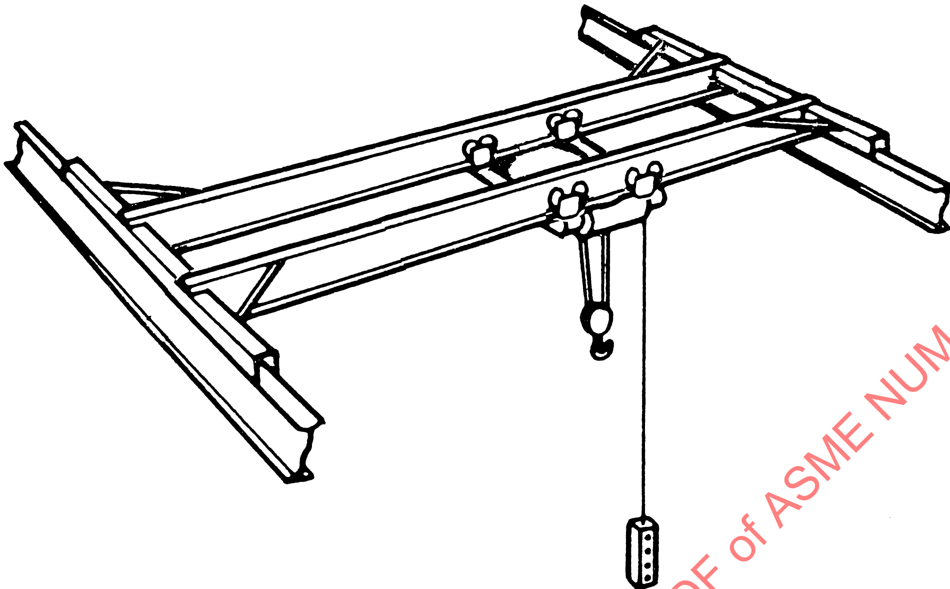


Figure GR-6.2.2-3
Top-Running Single-Girder Semi-Gantry Crane

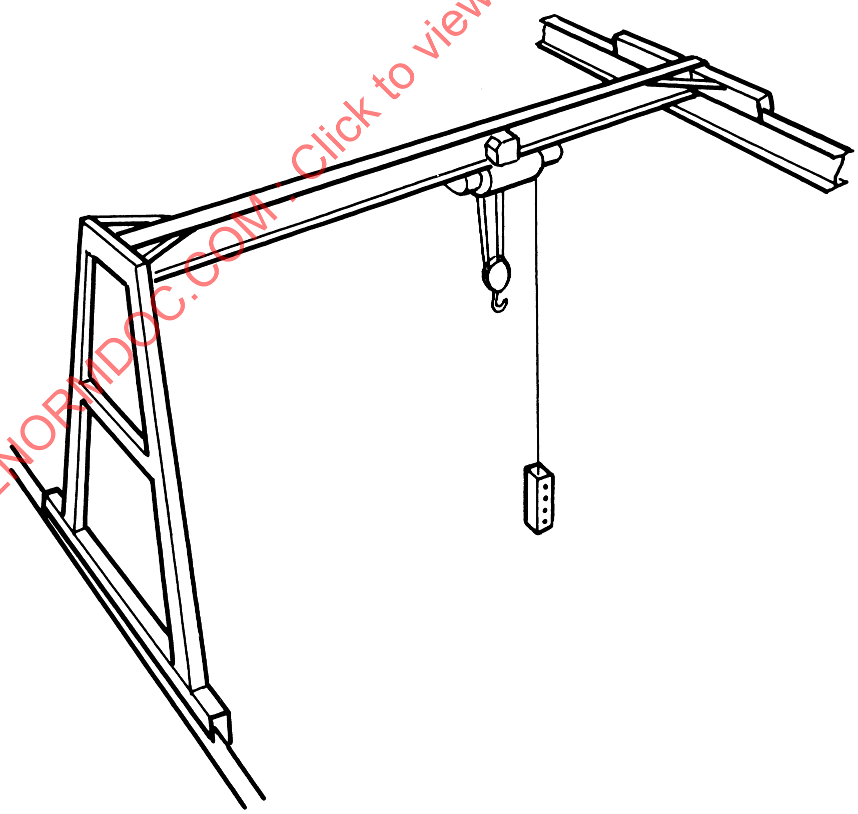


Figure GR-6.2.2-4
Top-Running Single-Girder Gantry Crane

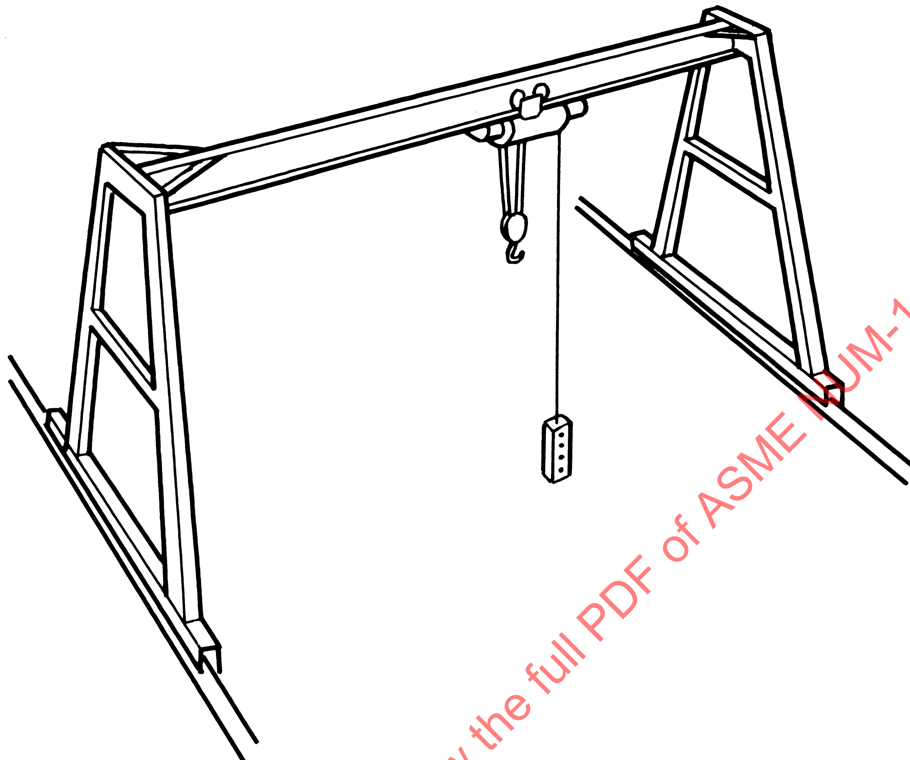


Figure GR-6.2.3-1
Traveling Wall Crane With Single-Girder Boom

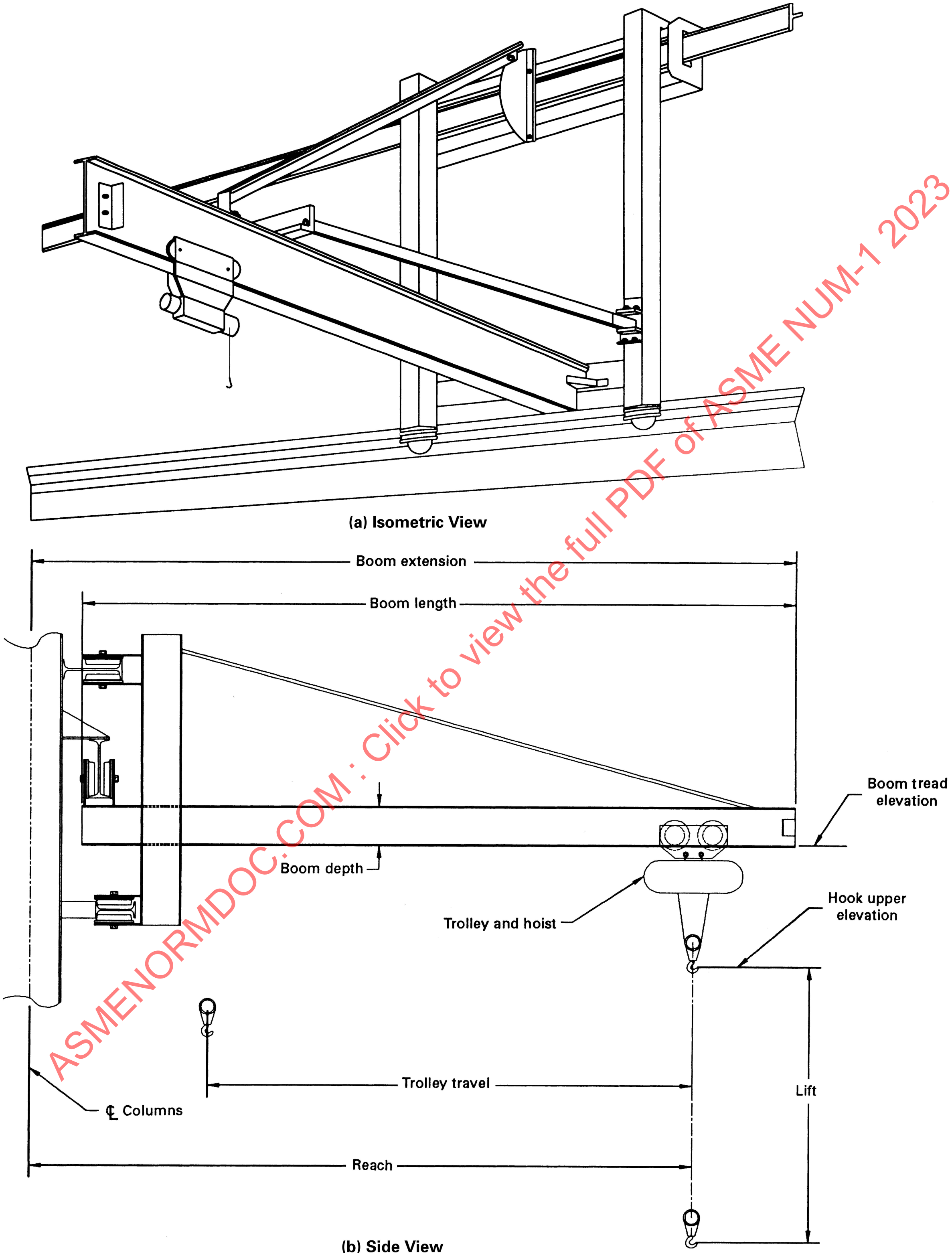
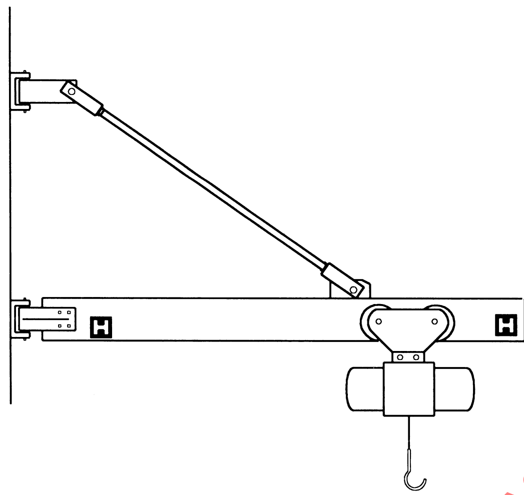
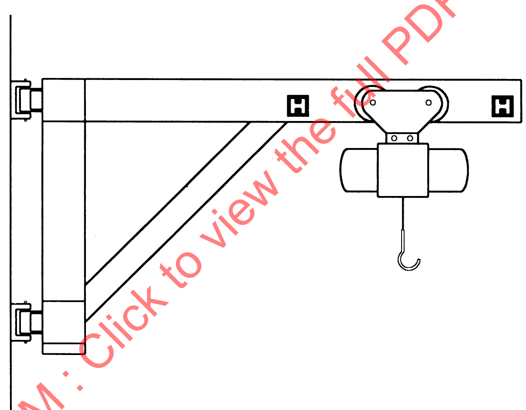


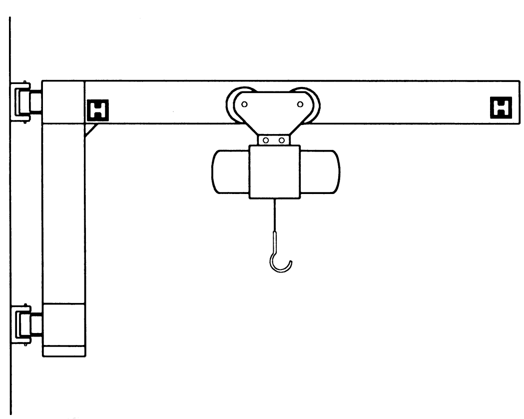
Figure GR-6.2.4-1
Wall-Mounted Jib Cranes



(a) Top-Braced Wall-Mounted Jib Crane

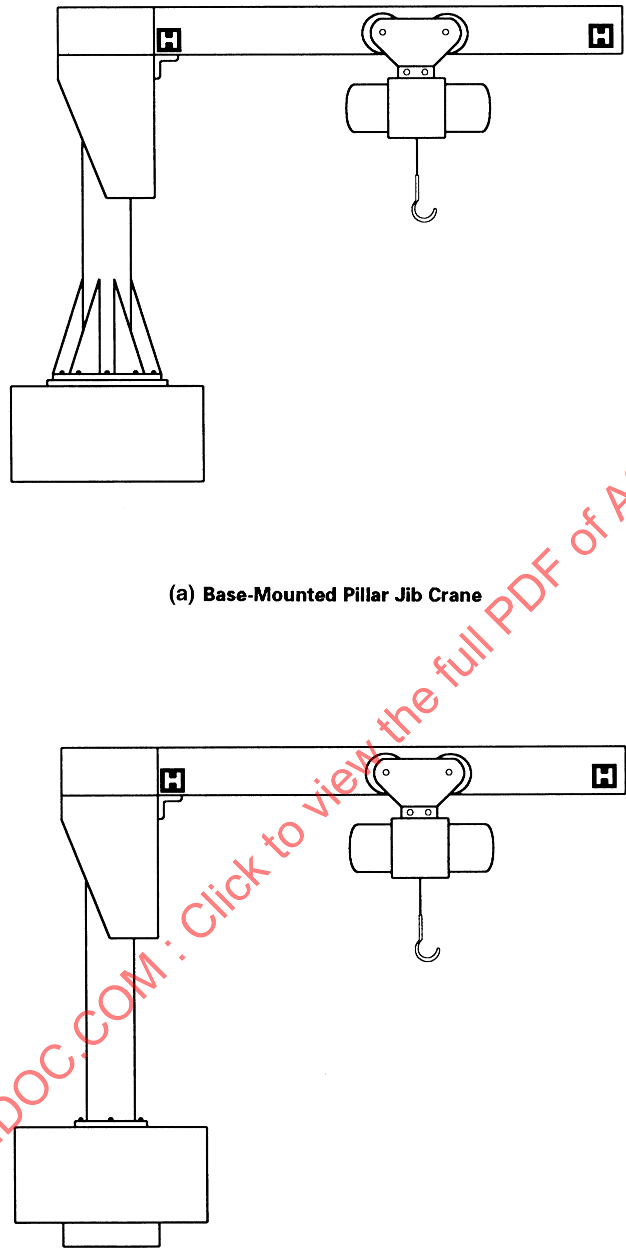


(b) Under-Braced Wall-Mounted Jib Crane



(c) Full-Cantilevered Wall-Mounted Jib Crane

Figure GR-6.2.4-2
Free-Standing Pillar Jib Cranes



(a) **Base-Mounted Pillar Jib Crane**

(b) **Insert-Mounted Pillar Jib Crane**

Figure GR-6.2.4-3
Mast-Type Jib Cranes

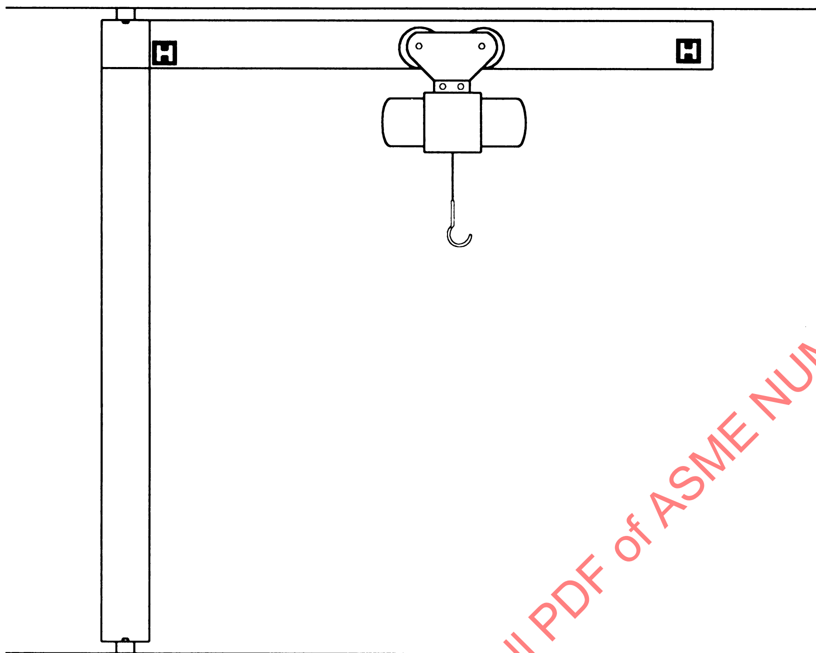


Figure GR-6.2.5-1
Basic Monorail System

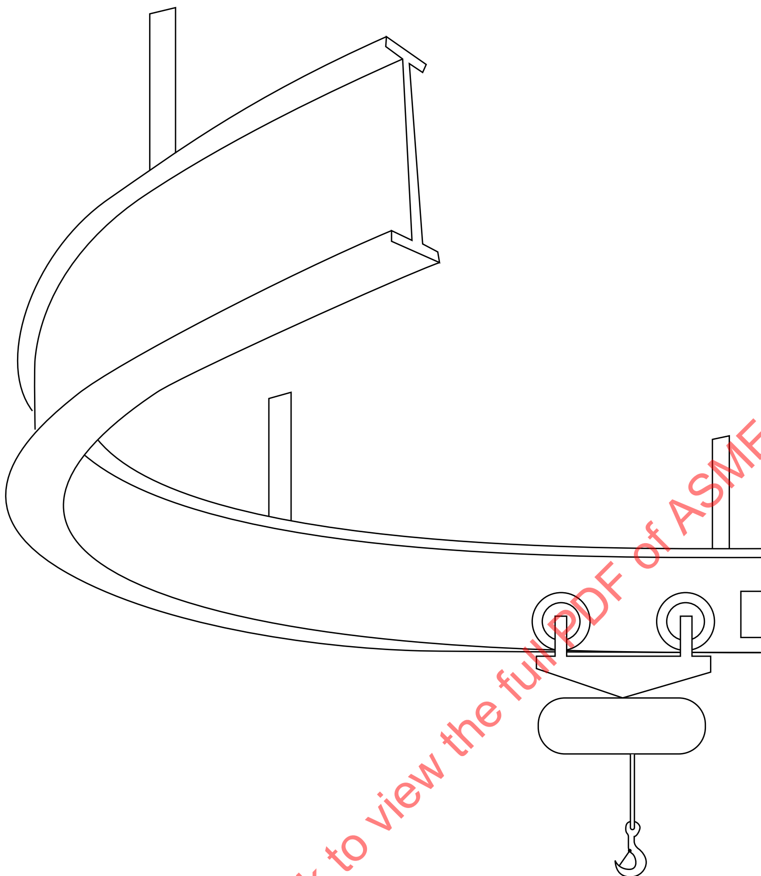


Figure GR-6.2.5-2
Two-Way Switch Monorail System

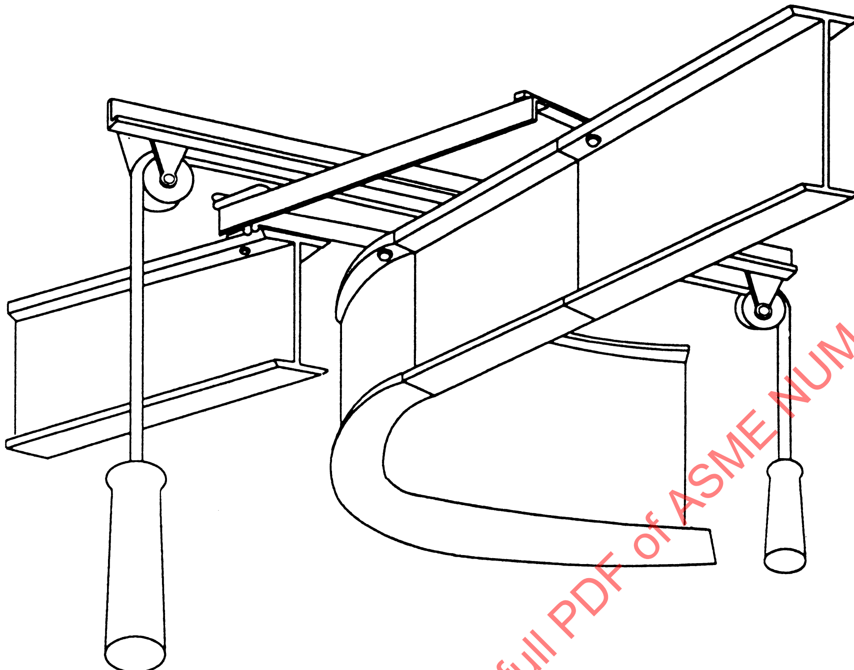


Figure GR-6.2.5-3
Three-Way Switch Monorail System

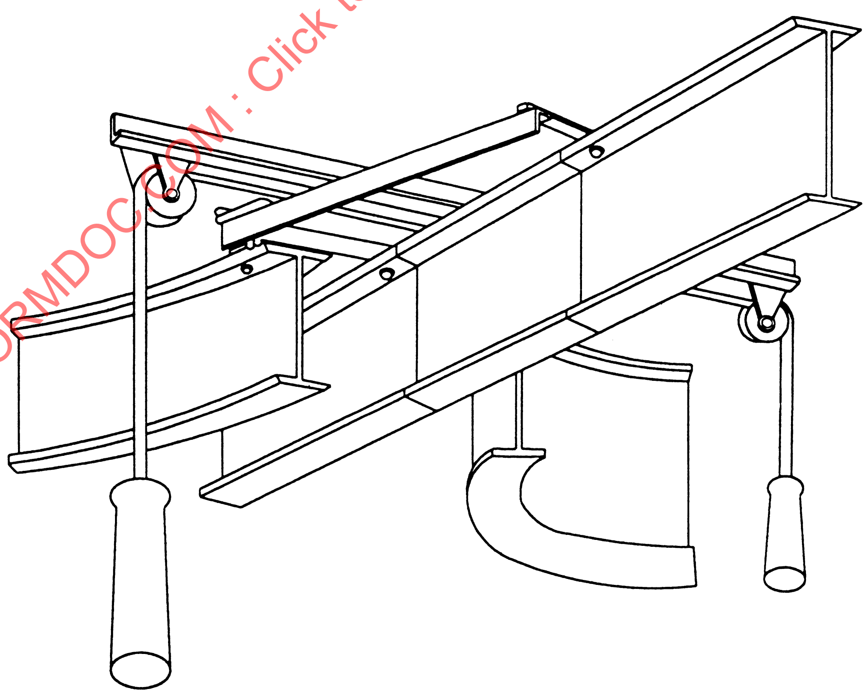


Figure GR-6.2.5-4
Cross-Track Switch Monorail System

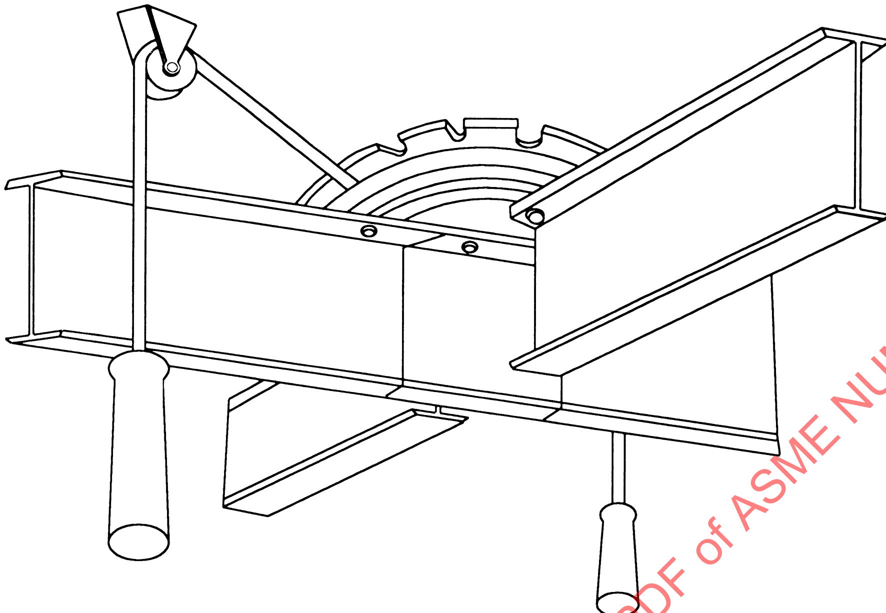


Figure GR-6.2.5-5
Interlocking-Mechanism Monorail System

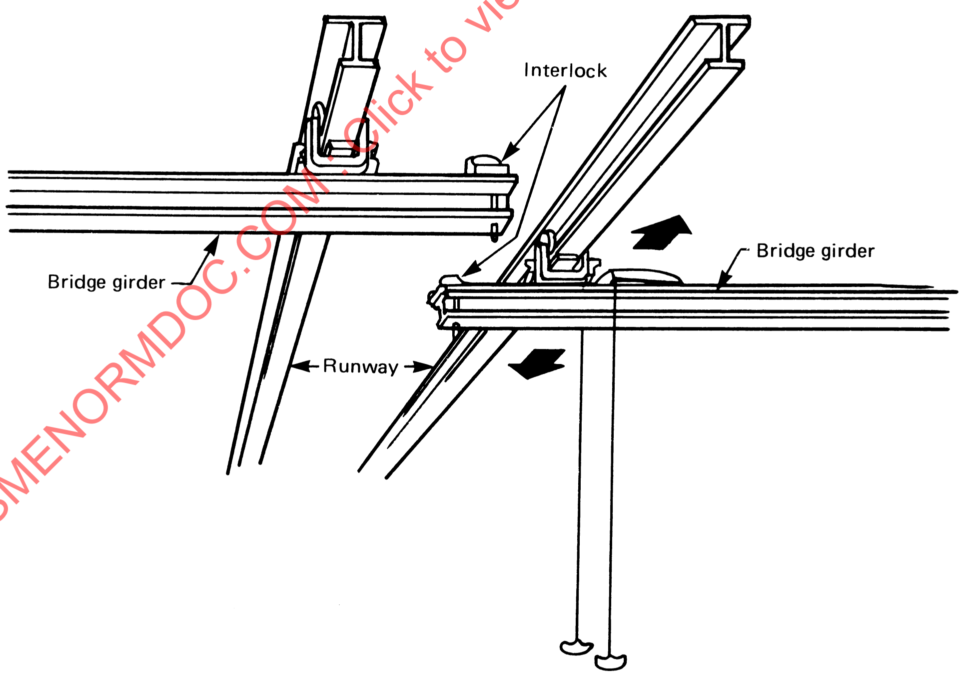


Figure GR-6.2.5-6
Monorail System With Lift–Drop Sections

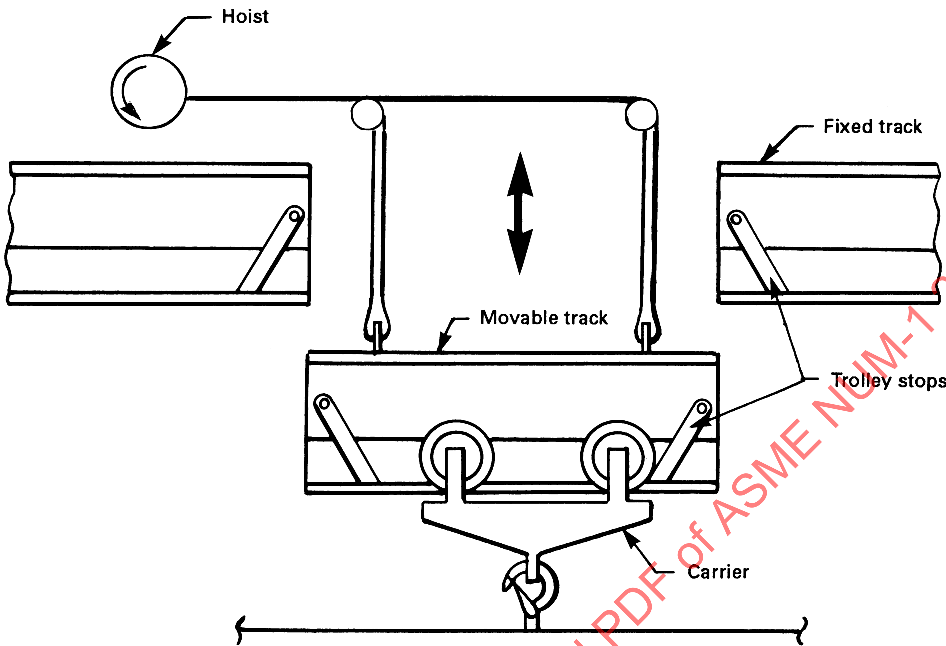


Figure GR-6.2.6-1
Hand-Chain-Operated Under-Running Trolley

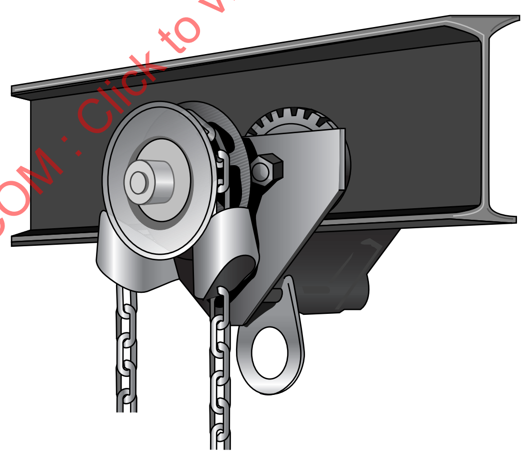


Figure GR-6.2.7-1
Electric Wire Rope Hoist

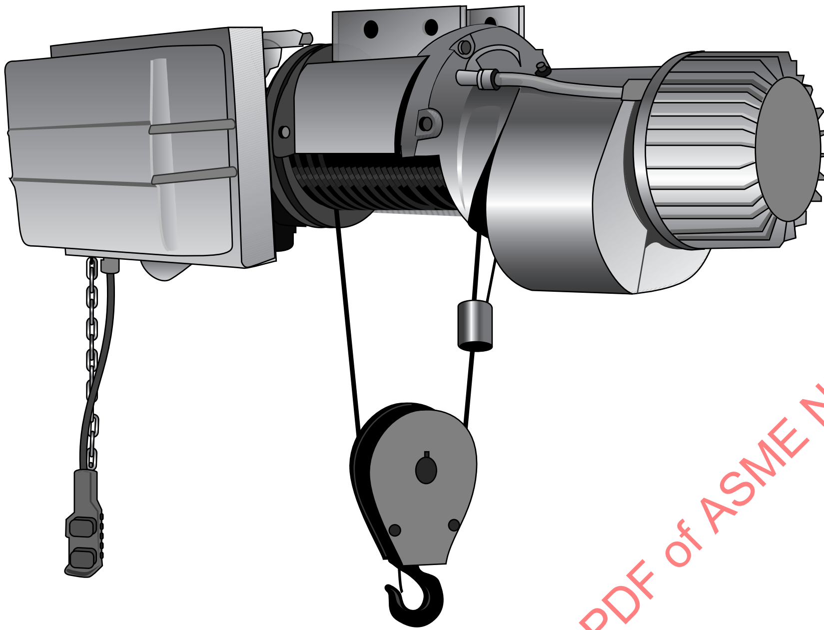


Figure GR-6.2.7-2
Hand-Chain Hoist

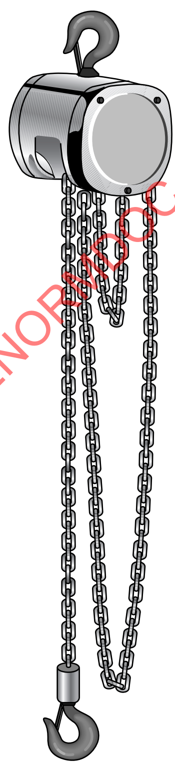


Figure GR-6.2.7-3
Electric Chain Hoist

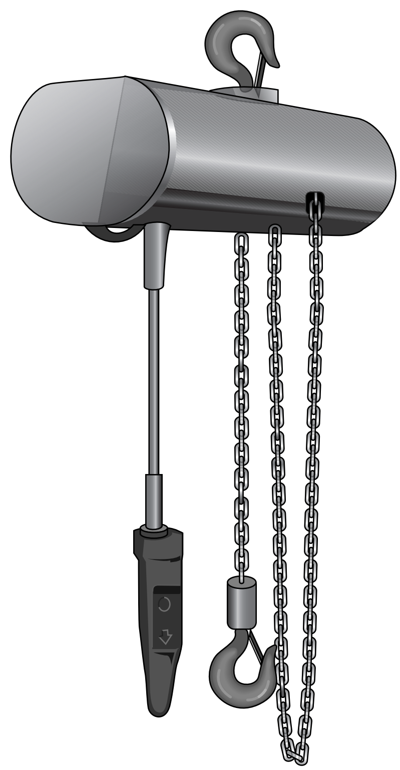


Figure GR-6.2.7-4
Air-Operated Wire Rope Hoist

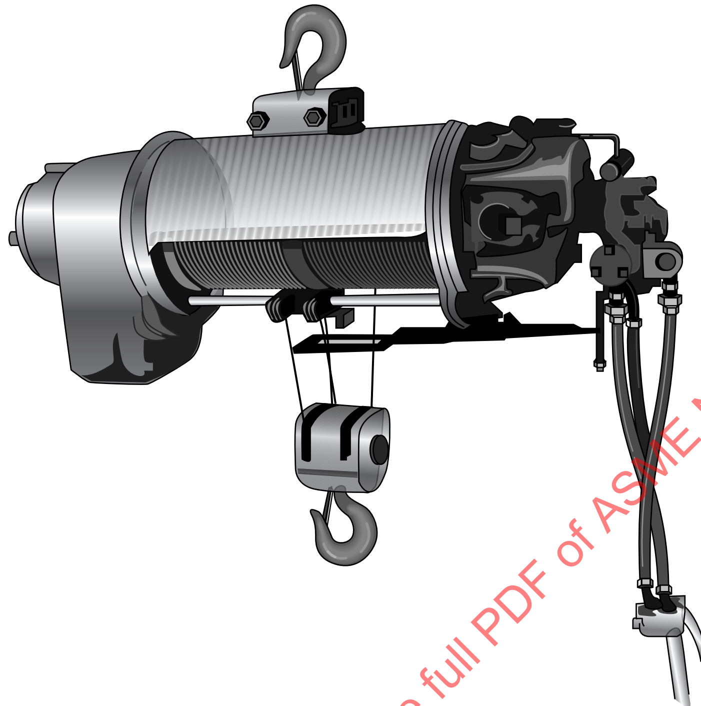


Figure GR-6.2.7-5
Air-Operated Chain Hoist

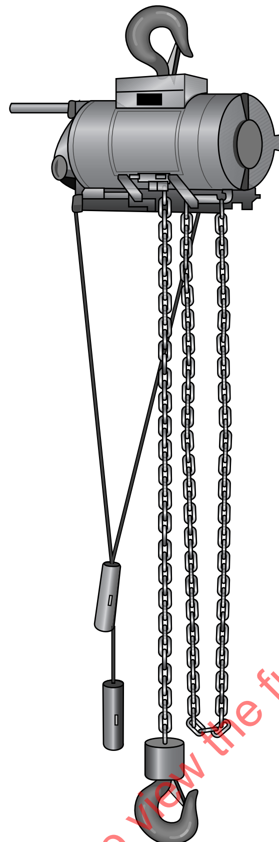
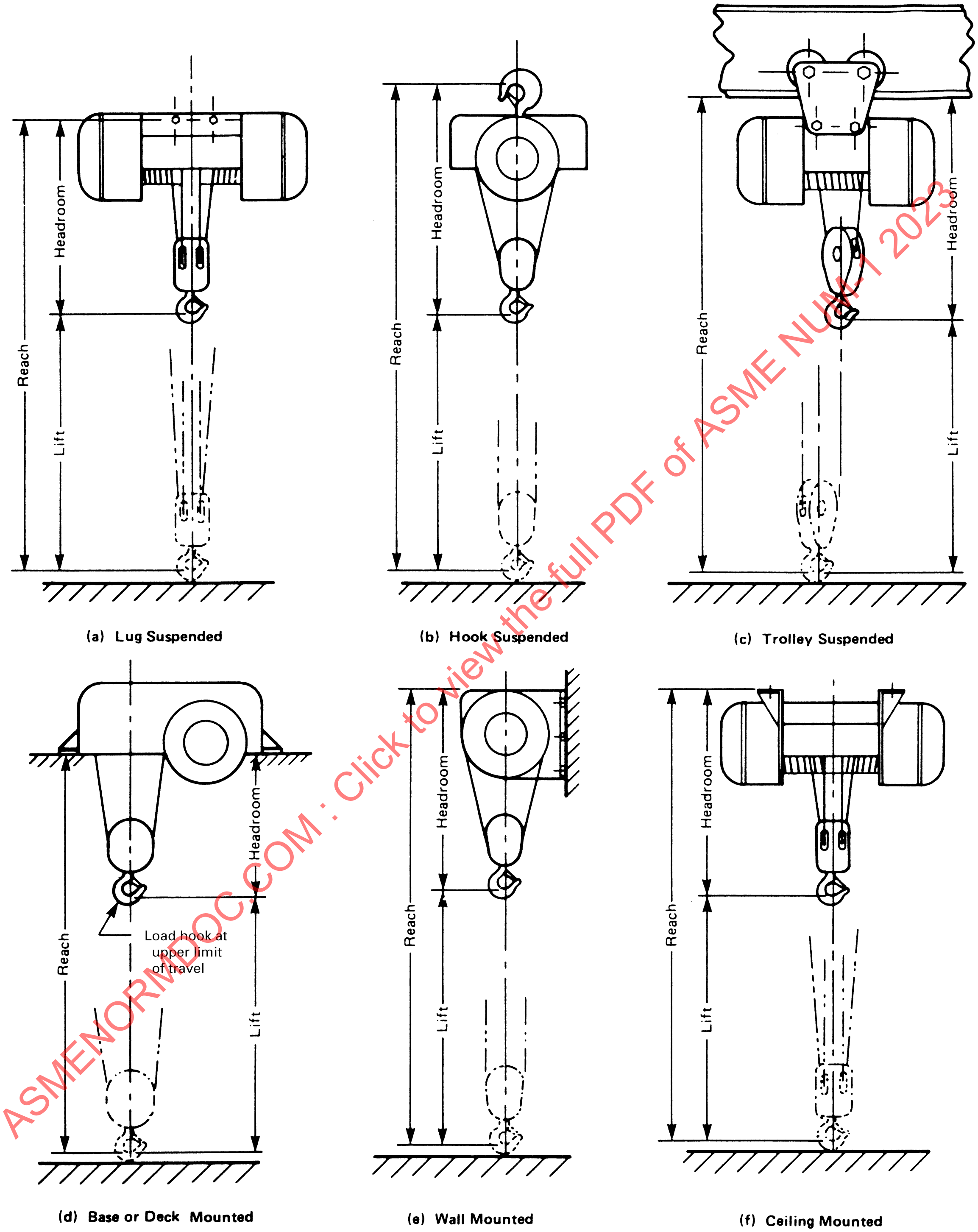


Figure GR-6.2.7.1-1
Electric- and Air-Operated Wire Rope Hoist Suspension Types



GENERAL NOTE: Illustrations shown are not intended to confine the use of single or double reeving. Each of the mountings may be used with either type of reeving.

Figure GR-6.2.7.1-2
Hand-Chain Hoist Suspension Types

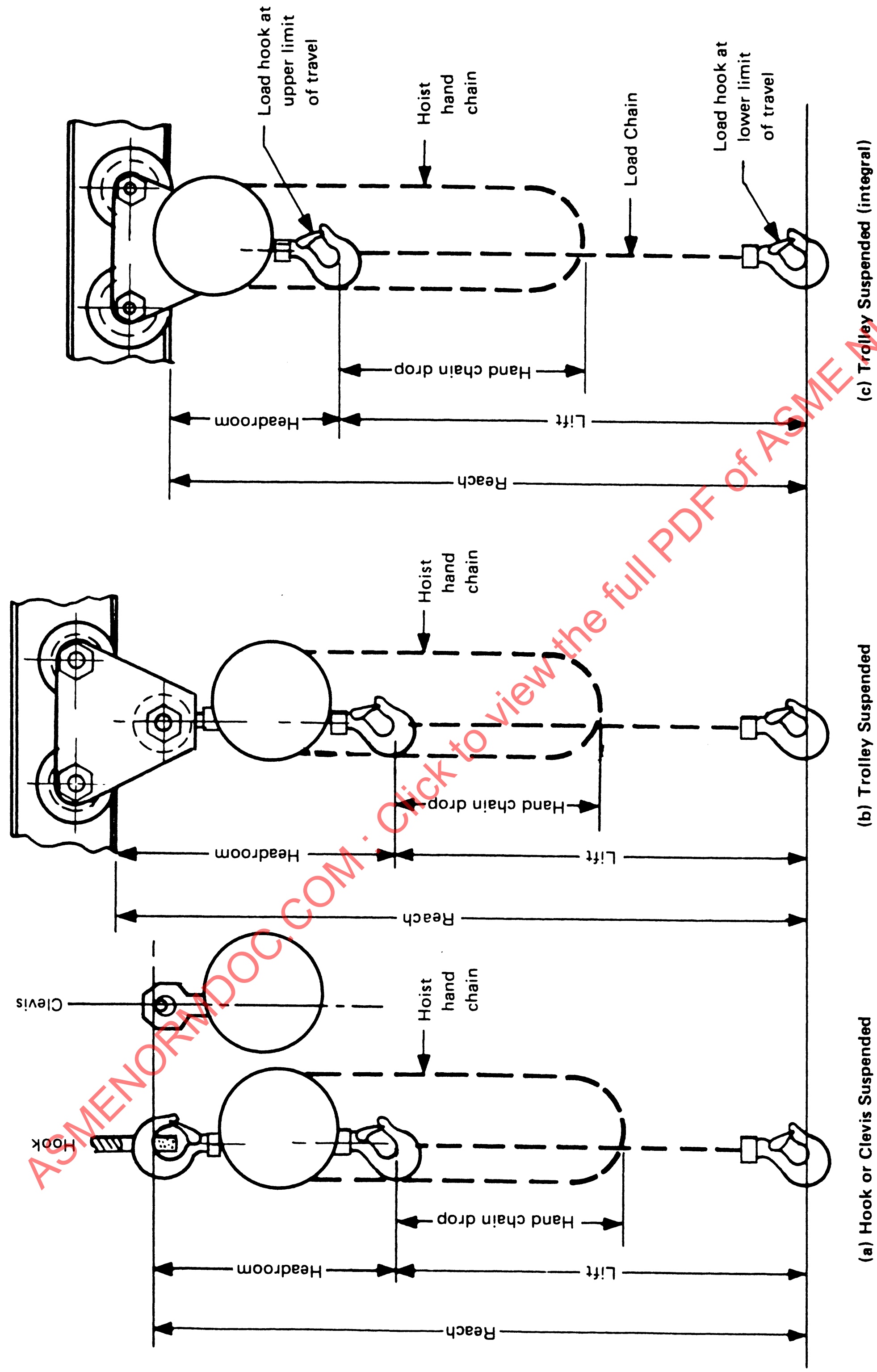
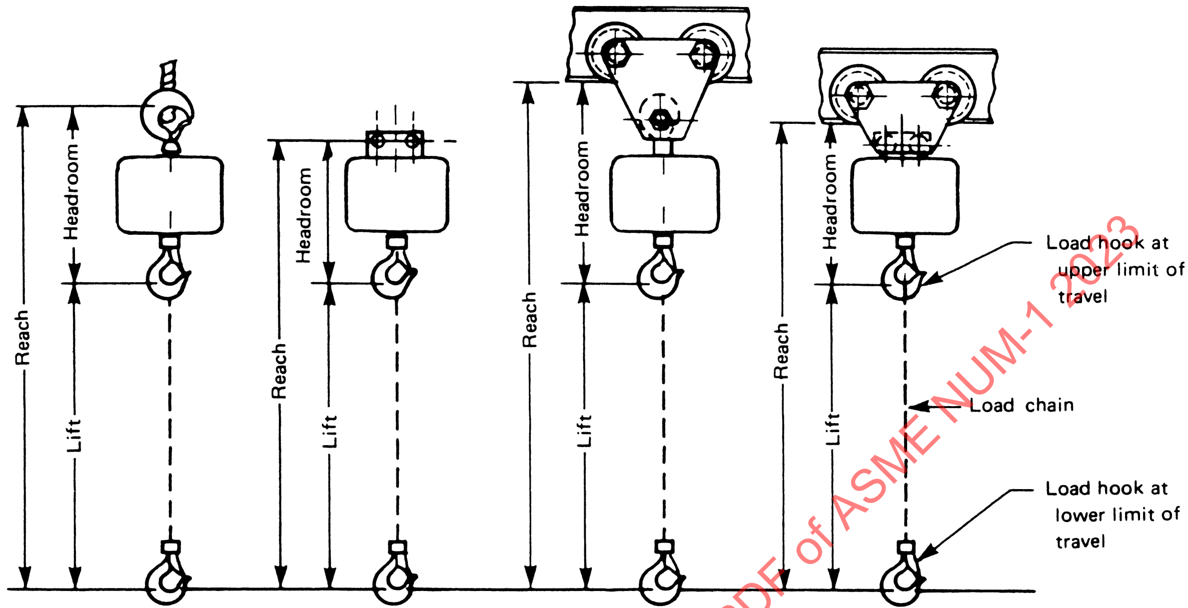


Figure GR-6.2.7.1-3
Electric- and Air-Operated Chain Hoist Suspension Types



(a) Hook or Clevis Suspended (b) Lug Suspended (c) Trolley Suspended (d) Trolley Suspended (Integral)

Section GR-7
Referenced Codes and Standards

GR-7.1 GENERAL

This Standard references portions of other specifications. Where conflict occurs, this Standard shall prevail. The following is a list of publications referenced in this Standard. Unless otherwise noted, the latest edition applies.

AISC Manual of Steel Construction: Allowable Stress Design (9th ed.) (1989). American Institute of Steel Construction.

AISE Standard No. 1. D-C MILL Motors. Association of Iron and Steel Engineers.

Annual Book of ASTM Standards (2007). ASTM International.

ANSI/AGMA 2001-D04 (R2010). Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth. American Gear Manufacturers Association.

ANSI/AGMA 9005-E02. Industrial Gear Lubrication. American Gear Manufacturers Association.

ASCE/SEI 7-10. Minimum Design Loads in Buildings and Other Structures. American Society of Civil Engineers.

ASME B30.10-2019. Hooks. The American Society of Mechanical Engineers.

ASME B30.16-2022. Overhead Underhung and Stationary Hoists. The American Society of Mechanical Engineers.

ASME B30.17-2020. Cranes and Monorails (With Underhung Trolley or Bridge). The American Society of Mechanical Engineers.

ASME HST-1–2017. Performance Standard for Electric Chain Hoists. The American Society of Mechanical Engineers.

ASME HST-2–2018. Performance Standard for Hand Chain Manually Operated Chain Hoists. The American Society of Mechanical Engineers.

ASME HST-4–2021. Performance Standard for Overhead Electric Wire Rope Hoists. The American Society of Mechanical Engineers.

ASME HST-5–2020. Performance Standard for Air Chain Hoists. The American Society of Mechanical Engineers.

ASME HST-6–2020. Performance Standard for Air Wire Rope Hoists. The American Society of Mechanical Engineers.

ASME NOG-1–2020. Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder). The American Society of Mechanical Engineers.

ASME NQA-1–2022. Quality Assurance Requirements for Nuclear Facility Applications. The American Society of Mechanical Engineers.

ASTM A36/A36M-12. Standard Specification for Carbon Structural Steel. ASTM International.

ASTM A48/A48M-03 (2012). Specification for Gray Iron Castings. ASTM International.

ASTM A53/A53M. Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless. ASTM International

ASTM A242/A242M. Standard Specification for High-Strength Low-Alloy Structural Steel. ASTM International.

ASTM A275/A275M-98. Standard Test Method for Magnetic Particle Examination of Steel Forgings. ASTM International.

ASTM A325-10. Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength. ASTM International.

ASTM A333/A333M. Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service. ASTM International.

ASTM A370-10. Standard Test Methods for Mechanical Testing of Steel Products. ASTM International.

ASTM A388/A388M-10. Standard Practice for Ultrasonic Examination of Steel Forgings. ASTM International.

ASTM A390. Standard Specification for Zinc-Coated (Galvanized) Steel Poultry Fence Fabric (Hexagonal and Straight Line). ASTM International.

ASTM A435/A435M-90. Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates. ASTM International.

ASTM A490-12. Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength. ASTM International.

ASTM A500/A500M. Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes. ASTM International.

ASTM A501/A501M. Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing. ASTM International.

ASTM A516/A516M. Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service. ASTM International.

ASTM A537/A537M. Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel. ASTM International.

ASTM A572/A572M. Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel. ASTM International.

ASTM A588/A588M. Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, With Atmospheric Corrosion Resistance. ASTM International.

ASTM A618/A618M-21. Standard Specification for Hot-Formed Welded and Seamless High Strength Low-Alloy Structural Tubing. ASTM International.

ASTM A633/A633M-18. Standard Specification for Normalized High-Strength Low-Alloy Structural Plates. ASTM International.

ASTM A709/A709M. Standard Specification for Structural Steel for Bridges. ASTM International.

ASTM A737/A737M. Standard Specification for Pressure Vessel Plates, High-Strength, Low-Alloy Steel. ASTM International.

ASTM A913/A913M. Standard Specification for High-Strength Low-Alloy Steel Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST). ASTM International.

ASTM A992/A992M. Standard Specification for Steel for Structural Shapes for Use in Building Framing. ASTM International.

ASTM B8-99. Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft. ASTM International.

ASTM B174-02. Specification for Bunch-Stranded Copper Conductors for Electrical Conductors. ASTM International.

ASTM D5144-00. Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants. ASTM International.

ASTM D5161-04. Standard Guide for Specifying Inspection Requirements for Coating and Lining Work (Metal Substrates). ASTM International.

ASTM E23. Standard Test Methods for Notched Bar Impact Testing of Metallic Materials. ASTM International.

ASTM E114-10. Standard Practice for Ultrasonic PulseEcho Straight-Beam Contact Testing. ASTM International.

ASTM E165-02. Standard Test Method for Liquid Penetrant Examination. ASTM International.

ASTM E208-06. Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels. ASTM International.

ASTM E380-93. Standard Practice for Use of the International System of Units (SI) (The Modernized Metric System). ASTM International.

ASTM E709-21. Standard Guide for Magnetic Particle Examination. ASTM International.

AWS D1.1/D1.1M:2020 with 2022 errata. Structural Welding Code — Steel. American Welding Society.

AWS D14.1:2005-AMD1. Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment. American Welding Society.

CMAA 74-2000. Specifications for Top Running and Under Running Single Girder Electric Overhead Cranes Utilizing Under Running Trolley Hoist. Crane Manufacturers Association of America.

CMAA 74-2020. Single Girder Cranes. Crane Manufacturers Association of America.

NEMA ICS 1-2022. Industrial Control and Systems, General Requirements. National Electrical Manufacturers Association.

NEMA ICS 6-1993 (R2016). Industrial Control and Systems: Enclosures. National Electrical Manufacturers Association.

NEMA MG-1. Motors and Generators. National Electrical Manufacturers Association.

NFPA 70 (2023). National Electrical Code. National Fire Protection Association.

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PART CM
CRANES AND MONORAILS

Section CM-1
Introduction, Cranes and Monorails (Types I and II)

CM-1.1 GENERAL

(a) As stated in Section GR-1, this Standard provides the criteria for Type I and Type II cranes and monorails.

(1) The Type I crane or monorail has enhanced safety designs and features for handling a critical load. Hoists installed on a Type I crane or monorail shall be Type IA or Type IB as addressed under Part HT. All sections of Part CM apply to Type I cranes and monorails.

(2) The Type II crane or monorail is not used to handle a critical load but is designed and constructed to remain in place during a seismic event. The mechanical, electrical, and pneumatic components of a Type II crane or monorail shall be designed in accordance with general industry standards but shall remain in place during a seismic event. Hoisting equipment used on a Type II crane or monorail shall be designed in accordance with general industry standards but shall also remain in place during a seismic event. Only the following sections of Part CM apply to Type II cranes and monorails:

(-a) Section CM-2, Structural

(-b) Section CM-6, Marking

(-c) Section CM-7, Inspection and Tests

(b) This Standard does not cover Type III cranes and monorails. Type III cranes and monorails shall comply with general industry standards.

(c) The specific Type I and Type II crane and monorail configurations addressed in Part CM are as follows:

(1) underhung cranes

(2) top-running bridge and gantry cranes with underhung trolleys

(3) traveling wall cranes

(4) jib cranes

(5) monorail systems

The requirements of Part CM apply to all the above equipment configurations unless a requirement is indicated as applying to one or more specific equipment configurations.

(d) The cranes and monorails of Part CM shall also comply with the following general requirements of Part GR:

(1) Section GR-2, Environmental Conditions of Service

(2) Section GR-3, Performance Requirements

(3) Section GR-4, Coatings and Finishes

(4) Section GR-5, Quality Assurance

Additional information and criteria are provided in Section GR-1, definitions are provided in Section GR-6, and a list of referenced codes and standards is provided in Section GR-7.

Section CM-2
Structural Requirements, Cranes and Monorails (Types I and II)

CM-2.1 GENERAL REQUIREMENTS FOR ALL CRANES AND MONORAILS

This Section covers the design, design criteria, materials, and fabrication procedures for the structural components that apply to all Type I and Type II cranes and monorails.

CM-2.1.1 Load Categories

Loads acting on the structure are divided into the following six categories and shall be considered during design:

(a) principal loads, including dead loads, lifted loads, and inertia forces

(b) additional loads, including operating wind loads and skewing

(c) extraordinary loads, including stored wind loads and collision forces

(d) extreme loads, including tornado wind loads, earthquake safe shutdown load, seismic lifted loads, and extreme overload

(e) torsional forces and moments

(f) abnormal event load

Test loads are specified in para. CM-7.1.7.4.

CM-2.1.1.1 Principal Loads

(a) Dead Load, DL. The dead load, DL, is the weight of all effective parts of the bridge structure, machinery parts, and fixed equipment supported by the structure.

(b) Trolley Load, TL. The trolley load, TL, is the weight of the trolley and the equipment attached to the trolley.

(c) Lifted Load, LL. The lifted load, LL, is the combination of the weight of the load and the lifting devices used for handling and holding the load, such as the load block, lifting beam, bucket, magnet, grab, and other supplemental devices.

(d) Vertical Inertia Forces for Motorized Cranes and Hoists. Vertical inertia forces include forces due to the motion of the crane and crane components (dead load forces) and forces due to raising or lowering of a load (hoist load forces). These forces shall be included by multiplication of the simplified factors defined below with the applicable dead loads and lifted loads.

(1) Dead Load Factor, DLF. The dead load factor, DLF, covers only the dead loads of the crane, trolley, and their associated equipment. The dead load factor is between 10%-20% based on the travel speed of the crane or monorail as determined using the following:

$$\text{DLF} = 1.1 \leq 1.05 + \frac{\text{travel speed, ft/min}}{2{,}000} \leq 1.2$$

(2) Hoist Load Factor, HLF. The hoist load factor, HLF, applies to the motion of the lifted load in the vertical direction and covers inertia forces, mass forces due to the sudden lifting of the load, and uncertainties allowing for other influences. The hoist load factor is 0.5% of the hoisting speed in feet per minute, but not less than 15% or more than 50%, except for bucket and magnet cranes, for which the impact value shall be taken as 50% of the rated capacity of the bucket or magnet hoist.

$$\text{HLF} = 0.15 \leq 0.005 \times \text{hoist speed} \leq 0.5$$

(e) Inertia Forces From Motorized Drives, IFD. Inertia forces occur during acceleration or deceleration of horizontal drive motions and depend on the driving and braking torques applied by the drive units and brakes during each cycle.

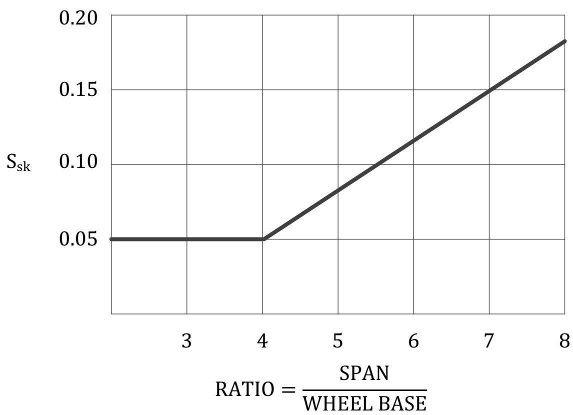
The inertia forces from motorized drives, IFD, shall be 7.8% of the acceleration or deceleration rate (in feet per seconds squared) but not less than 2.5%. The resulting drive inertia force is based on 250% of the nominal acceleration or deceleration rate produced by either the drive motor or brake. This percentage shall be applied to both the live and dead loads, exclusive of the end trucks. The live load shall be located in the same position as when calculating the vertical moment. The moment of inertia of the entire girder section about its vertical axis shall be used to determine the stresses due to lateral forces. The inertia forces during acceleration and deceleration shall be calculated in each case with the trolley in the worst position for the component being analyzed.

$$\begin{aligned}\text{IFD} &= (2.50/32.5) \times \text{acceleration or deceleration rate, ft/sec}^2 \geq 0.025 \\ &= 0.078 \times \text{acceleration or deceleration rate, ft/sec}^2 \geq 0.025\end{aligned}$$

CM-2.1.1.2 Additional Loads

(a) Operating Wind Load, WLO. Lateral load due to wind, called the operating wind load, WLO, shall be considered as an operating load of 5 lb/ft^2 of effective area.

Figure CM-2.1.1.2-1
Wheel-Skewing Forces



GENERAL NOTE: The figure, from CMAA 74-2020, para. 3.3.2.2.2, is reprinted courtesy of the Crane Manufacturers Association of America.

Where multiple surfaces are exposed to wind, such as crane girder and auxiliary girder, and the horizontal distance between surfaces is greater than the depth of the member on the windward side, consideration shall be given to increasing the effective area exposed to the wind. For single surfaces, such as cabs, the effective area shall be 1.2 times the projected area to account for negative pressure on the far side of the enclosure.

(b) Forces Due to Skewing, SK. When wheels roll along a rail, the horizontal forces normal to the rail and those tending to skew the structure shall be taken into consideration. The horizontal forces due to skewing, SK, shall be obtained by multiplying the vertical load exerted on each wheel by coefficient S_{sk}, which depends on the ratio of the span to the wheelbase (see Figure CM-2.1.1.2-1). The wheelbase is the distance between the outermost wheels.

CM-2.1.1.3 Extraordinary Loads

(a) Stored Wind Load, WLS. The stored wind load, WLS, is the maximum wind that a crane is designed to withstand during out-of-service conditions. The speed and test pressure vary with the height of the crane above the surrounding ground level, geographical location, and degree of exposure to prevailing winds (see ASCE/SEI 7-10).

(b) Collision Forces, CF. Special loading of the crane structure resulting from the bumper stops shall be calculated with the crane at 0.4 times the rated speed, assuming the bumper system is capable of absorbing the energy within its design scope. Loads suspended from lifting equipment and free oscillating loads need not be taken into consideration. Where the load cannot swing, the bumper effect shall be calculated in the same manner, taking into account the value of the load. The kinetic energy, KE, released on the collision of two cranes with the moving masses of M_1 and M_2 and a 40% maximum traveling speed of V_{T1} and V_{T2} shall be determined from eq. (CM-2-1).

$$\mathrm{KE} = \frac{M_1 M_2 (0.4 V_{T1} + 0.4 V_{T2})^2}{2(M_1 + M_2)} \tag{CM-2-1}$$

The bumper forces shall be distributed in accordance with the bumper characteristics and freedom of motion of the structure with the trolley in its worst position. Should the crane application require that maximum deceleration rates or stopping forces, or both, be limited due to suspended load or building structure considerations, or if bumper impact velocities greater than 40% of maximum crane velocity are to be provided for, such conditions shall be defined at the time of the crane purchase.

CM-2.1.1.4 Extreme Loads

(a) Tornado Wind Loads, WLT. Tornado wind loads, WLT, are not applicable to cranes and monorails unless specifically required by the owner. The wind speed varies with the height of the crane above the surrounding ground level, geographical location, and degree of exposure. Additional tornado-generated loads that should be considered are pressure drop and tornado missiles.

(b) Earthquake Safe Shutdown Load, E_s. The site SSE parameters shall be used in the seismic analysis of the crane or monorail to determine the earthquake safe shutdown load, E_s, following the guidance of para. CM-2.1.3.

(c) Seismic Lifted Load, SSE. For cranes and monorails, the seismic lifted load for an SSE (LL_{ES}) is the maximum lifted load under the evaluated seismic conditions where the crane or monorail structure must remain in place. The owner shall specify the seismic lifted load.

(1) For Type I equipment, the seismic lifted load shall be equal to the maximum critical load.

(2) Depending upon the facility-specific application, the requirement that Type II equipment remain in place during a seismic event may not require consideration of a seismic lifted load. The owner shall specify the seismic lifted load, if any, that shall be required.

(d) Extreme Overload, EOL. An extreme overload, EOL, is an overload that could be imposed on a crane or monorail structure from a Type IB hoist whose overload-limiting device cannot be set below 150% of the maximum critical load (MCL) rating. The owner shall specify the EOL, if any, that shall be required.

Table CM-2.1.2-1
Load Designations

Load	Load Designation
Trolley dead load	TL
Bridge dead load	DL
Lifted load	LL
Inertia forces from drives	IFD
Forces due to skewing	SK
Operating wind	WLO
Stored wind load	WLS
Tornado wind load	WLT
Collision forces	CF
Safe shutdown earthquake load	E_S
Maximum seismic lifted load	LL_{ES}
Extreme overload	EOL

CM-2.1.1.5 Torsional Forces and Moments

(a) Moment Due to the Starting and Stopping of Bridge Motors. The twisting moment due to the starting and stopping of bridge motors shall be considered as the starting torque of the bridge motor at 200% of full-load torque multiplied by the gear ratio between the motor and cross shaft.

(b) Moment Due to Vertical Loads. The torsional moment due to vertical forces acting eccentrically to the vertical neutral axis of the girder shall be considered as those vertical forces multiplied by the horizontal distance between the centerline of the forces and the shear center of the girder.

(c) Moment Due to Lateral Loads. The torsional moment due to the lateral forces acting eccentrically to the horizontal neutral axis of the girder shall be considered as those horizontal forces multiplied by the vertical distance between the centerline of the forces and the shear center of the girder.

CM-2.1.1.6 Abnormal Event Load. An abnormal event load, A_e, is a load caused by failure of plant equipment that imposes jet or missile loads on the crane. The owner shall be responsible for the effects of, and shall establish the criteria for, these loads.

CM-2.1.2 Loading Conditions

The loads described in para. CM-2.1.1 are listed in Table CM-2.1.2-1. The various load combinations, using the load designations shown, shall be calculated for the design cases listed herein.

(a) Case 1: Principal Loads. A crane or monorail in regular use under principal loading (stress level 1)

$$DL(DLF_B) + TL(DLF_T) + LL(1 + HLF) + IFD$$

where

DLF_B = bridge load factors

DLF_T = trolley load factors

(b) Case 2: Additional Loads. A crane or monorail in regular use under principal loading and additional loading

$$DL(DLF_B) + TL(DLF_T) + LL(1 + HLF) + IFD + WLO + SK$$

(c) Case 3: Extraordinary Loads

(1) A crane or monorail subjected to out-of-service wind

$$DL + TL + WLS$$

(2) A crane or monorail in collision

$$DL + TL + LL + CF$$

(d) Case 4: Extreme Loads

(1) A crane or monorail subjected to tornado wind load

$$DL + TL + WLT$$

(2) A crane or monorail subjected to an SSE is subject to the following loads:

$$DL + (TL + LL_{ES}) + E_S + WLO$$

$$DL + TL + E_S + WLO$$

(3) A crane or monorail whose structure could be subjected to an extreme overload as a result of a substantially higher overload limit setting of a Type IB hoist

$$DL + TL + EOL$$

CM-2.1.3 Seismic Analysis for Cranes and Monorails

CM-2.1.3.1 Methods of Analysis. A dynamic analysis method (e.g., response-spectrum or time-history method) or an equivalent static analysis shall be used to establish the response of the equipment to a seismic event.

CM-2.1.3.2 Seismic Input Data. The seismic input data for the equipment seismic analysis shall be provided by the owner. 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 or monorail.

CM-2.1.3.3 Load Pendulum Effects. Pendulum effects of the suspended load shall be considered. In most facilities, the horizontal load due to pendulum effects will be negligible because the load displacement is small. Where displacement is significant, consider obstacle-avoidance measures.

CM-2.1.3.4 Dynamic Analysis

CM-2.1.3.4.1 Response-Spectrum Method. The crane or monorail 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 requirements of para. CM-2.1.3.4. These outputs shall serve as the basis for mode-by-mode computation of the response of the crane or monorail to each of the three components of seismic input.

CM-2.1.3.4.2 Time-History Analysis. Time histories of structural response at the appropriate level may be used for analysis of the crane or monorail. The time histories shall be provided by the owner. Procedures for assembling the mathematical model shall be in accordance with para. CM-2.1.3.4. 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 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.

CM-2.1.3.4.3 Mathematical Model

(a) The crane or monorail shall be represented by a generalized three-dimensional system of nodes. The model's geometry shall reflect the overall size, length, connectivity, and stiffness 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 equipment.

(b) For cranes using pin-connected wheel trucks, pinned connections shall be specified for line elements that represent the attachment of the end trucks to the bridge girders or gantry legs. 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 stiffness values that are an order of magnitude higher than the stiffest 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 or monorail 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 model used for seismic analysis should be evaluated and revised if required to account for higher frequencies if plant operations induce such frequencies.

CM-2.1.3.4.4 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 equipment 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 or monorail 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.

CM-2.1.3.4.5 Decoupling Criteria for the Runway. The crane or monorail and runway shall be evaluated to determine if the equipment should be represented as a separate model or as a model coupled with the runway. For the equipment to be considered decoupled from the runway, the criterion of (a) or (b) shall be met.

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

(b) If 0.01 ≤ R_m ≤ 0.1, decoupling can be done if R_f ≤ 0.8 or if R_f ≥ 1.25.

(c) If R_m ≥ 0.2 or 0.8 ≤ R_f ≤ 1.25, an approximate model of the runway system shall be included with the model.

R_m and R_f are defined as

$$R_m = \frac{\text{total mass of the crane}}{\text{mass of the runway system}} \qquad \text{(CM-2-2)}$$

$$R_f = \frac{\text{fundamental frequency of the crane}}{\text{frequency of the dominant runway motion}} \qquad \text{(CM-2-3)}$$

The owner shall determine the mass and frequency characteristics of the runway.

CM-2.1.3.4.6 Boundary Conditions

(a) The crane or monorail shall be provided with 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 or monorail shall be included as boundary conditions in the model of the equipment. The restraint devices shall be considered to be in contact with the resisting structure in establishing boundary conditions used in the analysis for the crane or monorail. The restraint device and resisting structure shall be designed for the maximum load resulting from the boundary condition considered. The crane or monorail shall be modeled with the wheel-to-rail boundary conditions specified in Figure CM-2.1.3.4.6-1, unless additional restraining, driving, or holding mechanisms exist. The configurations shown in Table CM-2.1.3.4.6-1 were developed to show standard configurations. Other configurations are also acceptable.

(b) The crane or monorail boundary conditions at pivot points (such as hinges at jib crane connections) need to be modeled in computer analysis as rotationally fixed about the rotation of the hinge. If left free to rotate, the crane or monorail will be unstable, and the results of the analyses will be unrealistic. By fixing the rotation around the pin, the stresses in the crane or monorail will be conservative. During an actual seismic event, however, the crane or monorail will tend to rotate about these pivot points. It is the responsibility of the owner to determine if uncontrolled movement about the pivot point is acceptable (i.e., the crane or monorail movement will not impact and damage equipment). If uncontrolled movement is not acceptable, the owner shall specify that restraint devices be provided that will limit or dampen the movement.

(c) The crane or monorail boundary conditions at the point of interface with the building structure shall be determined by the person performing the crane or monorail analysis. The boundary conditions shall take into consideration the method of attachment and flexibility of connections.

CM-2.1.3.4.7 Trolley Locations and Hoist Positions. The crane or monorail shall be analyzed under the following loading conditions:

(a) seismic lifted load on hook (if specified)

(b) no load on hook

The analysis procedure shall use the bridge, jib, trolley, and hoist in as many different positions as necessary to envelop the worst-case loading situation. Since this Standard encompasses many different cranes and monorails, which may be fabricated and installed in many different configurations, it is the responsibility of the manufacturer to determine the worst-case configurations.

CM-2.1.3.4.8 Crane or Monorail 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 or monorail when the SSE is used in the analysis.

CM-2.1.3.4.9 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 or monorail. 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.

CM-2.1.3.4.10 Combination of Modal Responses. In combining the dynamic responses, it shall be assumed that the dynamic responses have the sign that yields the worst case for the combination being considered.

(a) With No Closely Spaced Modes. When the results of the modal dynamic analysis show that the crane or monorail modes are not closely spaced, the equipment'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.

(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:

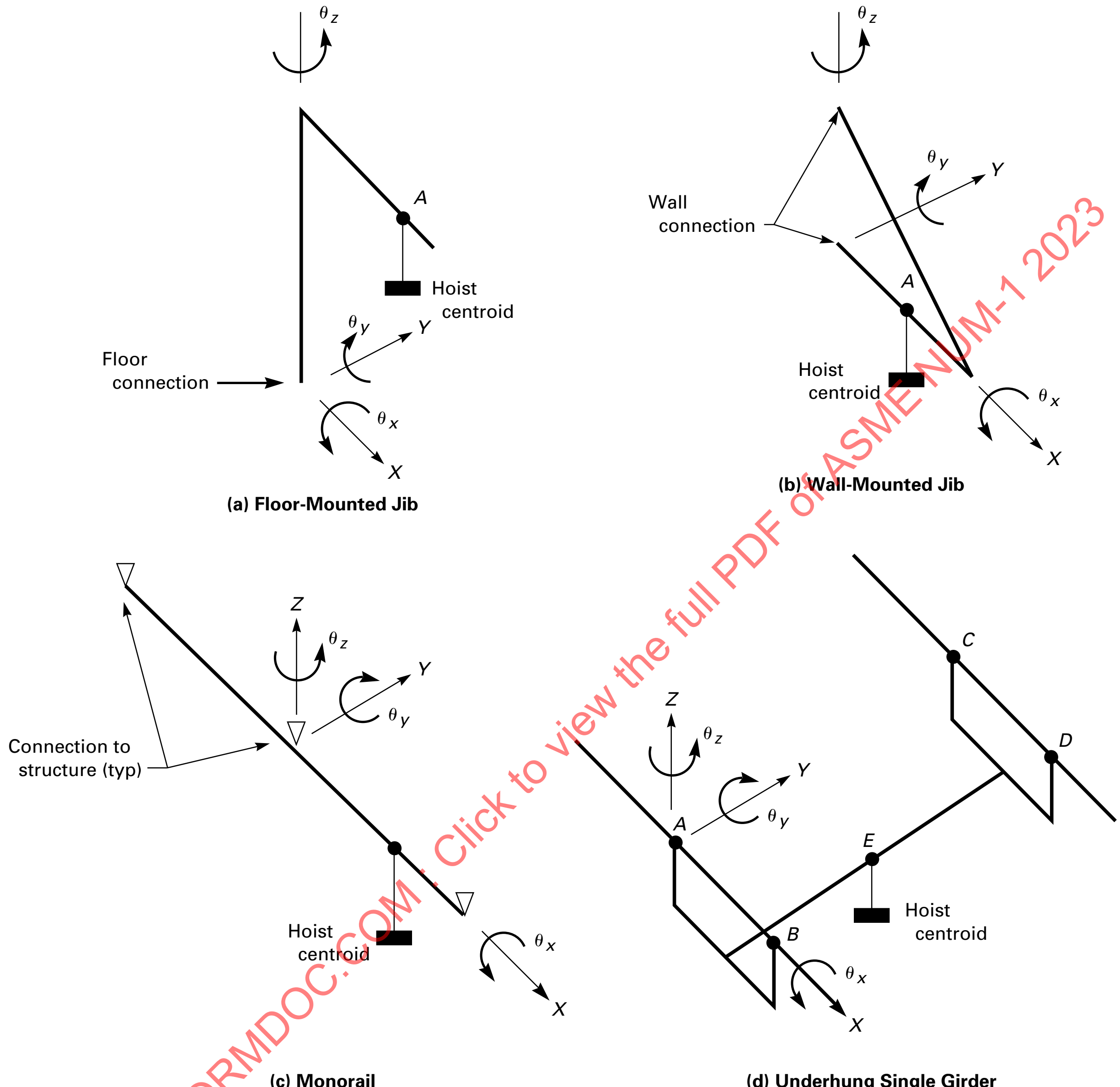
(1) Grouping Method. Closely spaced modes shall be divided into groups that include all modes with frequencies between the lowest frequency in the group and a frequency 10% higher [see Note]. The representative maximum value of a particular response of interest for the design of a given element of a nuclear power plant structure, system, or the crane or monorail 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 or monorail 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:

$$R = \left(\sum_{k=1}^{N} R_k^2 + \sum_{q=1}^{P} \sum_{l=i}^{j} \sum_{m=i}^{j} |R_{lq} R_{mq}| \right)^{1/2} \quad \text{(CM-2-4)}$$

where $l \neq m$ and

i = number of the mode where a group starts

Figure CM-2.1.3.4.6-1
Boundary Conditions for Wheel-to-Rail Interface



GENERAL NOTES:
(a) The hoist is modeled as a lumped mass at its centroid.
(b) The members are modeled at their centroidal axis.
(c) The nodes shown illustrate wheel-to-rail boundary conditions. Additional nodes are required to complete the mathematical model.

Table CM-2.1.3.4.6-1
Boundary Conditions for Wheel-to-Rail Interface

Node	Restraint Condition: Translation X	Y	Z	Rotation θ_x	θ_y	θ_z
Floor jib						
A	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Wall jib						
A	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Monorail						
A	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Underhung						
A	Fixed	Fixed	Fixed	Free	Free	Free
B	Free	Fixed	Fixed	Free	Free	Free
C	Fixed	Free	Fixed	Free	Free	Free
D	Free	Free	Fixed	Free	Free	Free
E	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed

GENERAL NOTE: The nodes are shown in Figure CM-2.1.3.4.6-1.

j = number of the mode where the group ends
N = number of significant modes considered in the modal response combination
R = representative maximum value of a particular response of a given element to a given component of an earthquake
P = number of groups of closely spaced modes, excluding individual, separated modes
R_k = peak value of the response of the element due to the kth mode
R_{lq}, R_{mq} = modal responses

(2) 10% Method

$$R = \left(\sum_{k=1}^{N} R_k^2 + 2\sum \left| R_i R_j \right| \right)^{1/2} \quad \text{(CM-2-5)}$$

where $i \neq j$ and N, R, and R_k are as defined in (1). The second summation shall be done on all i and j modes whose frequencies are closely spaced to each other. Let ω_I and ω_j be the frequencies of the ith and jth modes. To verify which modes are closely spaced, the following equation shall be applied:

$$\frac{\omega_j - \omega_i}{\omega_i} \leq 0.1 \quad \text{(CM-2-6)}$$

where

$$1 \leq i < j \leq N \quad \text{(CM-2-7)}$$

(3) Double-Sum Method

$$R = \left(\sum_{k=1}^{N} \sum_{s=1}^{N} |R_k R_s| \in_{ks} \right)^{1/2} \quad \text{(CM-2-8)}$$

where N, R, and R_k are as defined in (1) and
R_s = peak value of the response of the element attributed to the sth mode
$\in_{ks}$ = correlation coefficient between modes k and s

$$\in_{ks} = \left\{ 1 + \left[\frac{(\omega_k' - \omega_s')}{(\beta_k' \omega_k + \beta_s' \omega_s)} \right]^2 \right\}^{-1} \quad \text{(CM-2-9)}$$

$$\beta_k' = \beta_k + \frac{2}{t_d \omega_k} \quad \text{(CM-2-10)}$$

$$\omega_k' = \omega_k \left(1 - \beta_k^2\right)^{1/2} \quad \text{(CM-2-11)}$$

t_d = duration of the earthquake
β_k = damping ratio in the kth mode
β_k' = modified damping ratio of the kth mode
β_s' = modified damping ratio of the sth mode
ω_k = undamped natural frequency of the kth mode
ω_k' = damped natural frequency of the kth mode
ω_s = undamped natural frequency of the sth mode
ω_s' = damped natural frequency of the sth mode

NOTE: 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.

(c) Combination of Three Components of Earthquake Motion. The representative maximum values of the structural responses of each of the three directional components of earthquake motion shall be combined by taking the square root of the sum of the squares of the maximum m representative values of the codirectional responses caused by each of the three components of earthquake motion at each node of the crane or monorail mathematical model.

CM-2.1.3.5 Equivalent Static Analysis. In cases where a dynamic analysis is not necessary because the crane or monorail model is very simple (as in the case of a single-span monorail or simple jib crane), an equivalent static analysis can be performed.

CM-2.1.3.5.1 Mathematical Model. The crane or monorail shall be represented by a generalized three-dimensional system of nodes. The model's geometry shall reflect the overall size, length, connectivity, and stiffness 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 or monorail.

CM-2.1.3.5.2 Decoupling Criteria for the Runway. See para. CM-2.1.3.4.5.

CM-2.1.3.5.3 Trolley Locations and Hoist Positions. See para. CM-2.1.3.4.7.

CM-2.1.3.5.4 Crane or Monorail Damping Values. See para. CM-2.1.3.4.8.

CM-2.1.3.6 Number of Modes Required for Seismic Analysis. Only the fundamental frequency of the crane or monorail in each direction of earthquake is used. For fundamental frequencies less than or equal to the frequency at which the maximum spectral acceleration occurs, the maximum spectral acceleration shall be used. For fundamental frequencies greater than the frequency at which the maximum spectral acceleration occurs, the actual spectral acceleration depicted on the response spectra curve shall be used. The maximum spectral acceleration may conservatively be used without calculation of the fundamental frequency.

CM-2.1.3.7 Combination of Modal Responses. Since only one mode is calculated in each direction, an increase factor of 1.5 shall be used on the acceleration to account for other modes.

CM-2.1.3.8 Combination of Three Components of Earthquake Motion. The representative maximum values of the structural responses of each of the three directional 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 each node of the crane or monorail mathematical model.

CM-2.1.4 Tolerances

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 operating surface and centerline of the beam or rail. Cumulative measurements of crane components are permitted.

The runway shall be straight, parallel, level, and at the same elevation within the tolerances given in Figure CM-2.1.4-1 or Figure CM-2.1.4-2. The crane manufacturer shall design the crane to operate properly within the runway tolerances given in Figures CM-2.1.4-1 and CM-2.1.4-2.

CM-2.1.5 Materials and Connections

CM-2.1.5.1 Base Materials. The base materials listed in Table CM-2.1.5.1-1 are considered acceptable for structural components. The manufacturer shall list all structural materials used for the owner and shall provide the material tests and certifications as required in Table CM-2.1.5.1-2. Structural materials not listed in Table CM-2.1.5.1-1 may be acceptable with approval by the owner.

CM-2.1.5.2 Fastener Materials

(a) The bolts used for joining structural components shall be in accordance with para. CM-2.1.6.1.5.

(b) The fastener finish and tolerances shall be suitable for the type of connection in which they are employed.

CM-2.1.5.3 Welding Materials. All welding materials shall comply with the requirements of AWS D1.1 or AWS D14.1 as applicable.

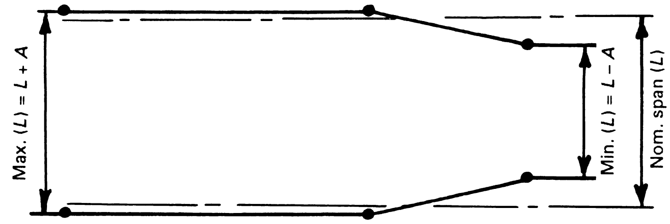
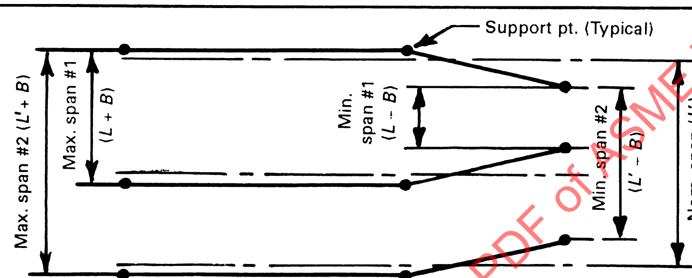
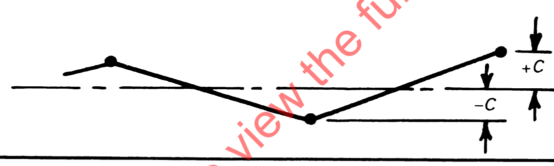
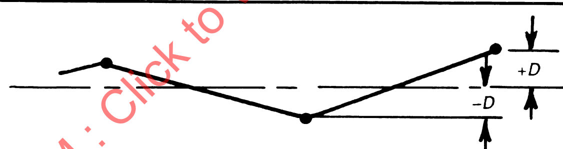
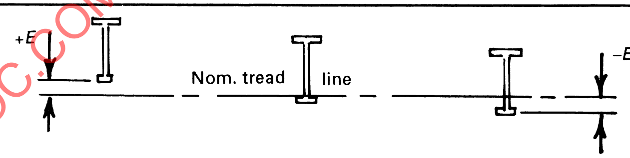
CM-2.1.5.4 Connections

CM-2.1.5.4.1 Welded Connections. Welded connections shall comply with the requirements of AWS D1.1 or AWS D14.1 as applicable.

CM-2.1.5.4.2 Bolted Connections

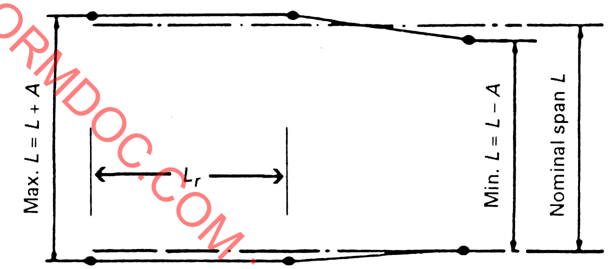
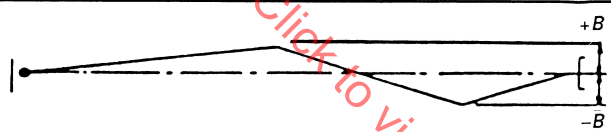
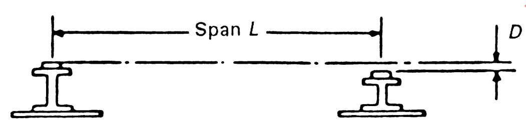
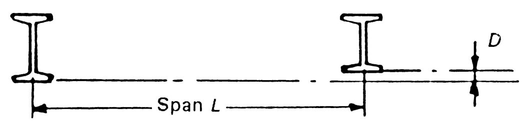
CM-2.1.5.4.2.1 Structural Joints Using ASTM A325 or ASTM A490 Bolts. Structural joints using ASTM A325 or ASTM A490 bolts shall be designed and installed in accordance with the "Specification for Structural Joints Using ASTM A325 and A490 Bolts" included in the AISC Manual of Steel Construction: Allowable Stress Design. Bolt holes shall not be burned. Standard holes shall have a maximum diameter $^1/_{16}$ in. in excess of the nominal bolt diameter. Holes for alignment (bound) bolts shall be reamed to close tolerances as required. Slotted bolt holes shall not be used for connections of end trucks.

Figure CM-2.1.4-1
Building Runway Alignment Tolerance for Patent Track

Item	Figure	Overall Tolerance
Crane span (L) measured at crane wheel contact surface		$A = {}^1/_8$ in. in any support span
Span (3 or more runways)		$B = {}^1/_8$ in. in any support span
Straightness		$C = {}^1/_8$ in. in any support span
Elevation		$D = {}^1/_8$ in. in any support span
Rail-to-rail elevation		$E = {}^1/_8$ in. between adjacent rails

GENERAL NOTE: The figure, from CMAA 74-2000, is reprinted courtesy of the Crane Manufacturers Association of America.

Figure CM-2.1.4-2
Building Runway Alignment Tolerance

Item	Figure	Overall Tolerance	Maximum Rate of Change
Crane span (L) measured at crane wheel contact surface		$L \leq 50$ ft, $A = {}^3/_{16}$ in. $L > 50$ ft ≤ 100 ft, $A = {}^1/_4$ in. $L > 100$ ft, $A = {}^3/_8$ in.	${}^1/_4$ in. in 20 ft 0 in.
Straightness (B)		$B = {}^3/_8$ in.	${}^1/_4$ in. in 20 ft 0 in.
Elevation (C)		$C = {}^3/_8$ in.	${}^1/_4$ in. in 20 ft 0 in.
Top-running transverse rail-to-rail elevation (D)		$L \leq 50$ ft, $D = \pm{}^3/_{16}$ in. 50 ft $< L \leq 100$ ft, $D = \pm{}^1/_4$ in. $L > 100$ ft, $D = \pm{}^3/_8$ in.	${}^1/_4$ in. in 20 ft 0 in.
Transverse girder-to-girder elevation underrunning (D)			

GENERAL NOTE: The figure, from CMAA 74-2000, is reprinted courtesy of the Crane Manufacturers Association of America.

Table CM-2.1.5.1-1
Acceptable Materials and Reference Properties for Structural Components

ASTM Specification	Grade or Class	Form	Size [Note (1)]	Yield Strength, ksi	Tensile Strength, ksi
A36/A36M	...	Plates, shapes, and bars	Plates and bars < 8 in. and shapes [for shapes, see Note (2)]	36 min.	58–80
A53/A53M	B	Pipe	Diameters ≤ 26 in.	35 min.	60 min.
A242/A242M	...	Plates, shapes, and bars	Plates and bars ≤ $\frac{3}{4}$ in. and shapes with flange or leg thickness ≤ $1\frac{1}{2}$ in.	50 min.	70 min.
A242/A242M	...	Plates, shapes, and bars	Plates and bars > $\frac{3}{4}$ in. and ≤ $1\frac{1}{2}$ in. and shapes with flange thickness > $1\frac{1}{2}$ in. and ≤ 2 in.	46 min.	67 min.
A242/A242M	...	Plates, shapes, and bars	Plates and bars > $1\frac{1}{2}$ in. and ≤ 4 in. and shapes with flange thickness > 2 in.	42 min.	63 min.
A333/A333M	3 and 7	Pipe	Diameters ≤ 26 in.	35 min.	65 min.
A333/A333M	4 and 6	Pipe	Diameters ≤ 26 in.	35 min.	60 min.
A500/A500M	B	Rectangular tubing	Wall ≤ $\frac{5}{8}$ in. and periphery ≤ 64 in. [Note (3)]	46 min.	58 min.
A501/A501M	...	Tubing	Square and rectangular with sides ≤ 10 in. and wall ≤ 1 in. and round ≤ 24 in. diameter and wall ≤ 1 in.	36 min.	58 min.
A516/A516M	65	Plates	Thickness ≤ 8 in.	35 min.	65–85
A516/A516M	70	Plates	Thickness ≤ 8 in.	38 min.	70–90
A537/A537M	1	Plates	Thickness ≤ $2\frac{1}{2}$ in.	50 min.	70–90
A537/A537M	1	Plates	Thickness > $2\frac{1}{2}$ in. and ≤ 4 in.	45 min.	65–85
A537/A537M	2	Plates	Thickness ≤ $2\frac{1}{2}$ in.	60 min.	80–100
A537/A537M	2	Plates	Thickness > $2\frac{1}{2}$ in. and ≤ 4 in.	55 min.	75–95
A537/A537M	2	Plates	Thickness > 4 in. and ≤ 6 in.	46 min.	70–90
A537/A537M	3	Plates	Thickness ≤ $2\frac{1}{2}$ in.	55 min.	80–100
A537/A537M	3	Plates	Thickness > $2\frac{1}{2}$ in. and ≤ 4 in.	50 min.	75–95
A537/A537M	3	Plates	Thickness > 4 in. and ≤ 6 in.	40 min.	70–90
A572/A572M	42	Plates, shapes, and bars	Plates and bars ≤ 6 in. and shapes	42 min.	60 min.
A572/A572M	50	Plates, shapes, and bars	Plates and bars ≤ 4 in. and shapes	50 min.	65 min.
A572/A572M	55	Plates, shapes, and bars	Plates and bars ≤ 2 in. and shapes	55 min.	70 min.
A572/A572M	60	Plates, shapes, and bars	Plates and bars ≤ $1\frac{1}{4}$ in. and shapes with flange or leg thickness ≤ 2 in.	60 min.	75 min.
A572/A572M	65	Plates, shapes, and bars	Plates and bars ≤ $1\frac{1}{4}$ in. and shapes with flange or leg thickness ≤ 2 in.	65 min.	80 min.
A588/A588M	...	Plates, shapes, and bars	Plates and bars < 4 in. and shapes	50 min.	70 min.
A588/A588M	...	Plates, shapes, and bars	Plates and bars > 4 in. and ≤ 5 in.	46 min.	67 min.
A588/A588M	...	Plates, shapes, and bars	Plates and bars > 5 in. and ≤ 8 in.	42 min.	63 min.
A618/A618M	IA, IB, and II	Tubing	Wall ≤ $\frac{3}{4}$ in.	50 min.	70 min.
A618/A618M	IA, IB, and II	Tubing	Wall > $\frac{3}{4}$ in. and ≤ $1\frac{1}{2}$ in.	46 min.	67 min.
A618/A618M	III	Tubing	All tubing	50 min.	65 min.
A633/A633M	A	Plates	Thickness ≤ 4 in.	42 min.	63–83
A633/A633M	C and D	Plates	Thickness ≤ $2\frac{1}{2}$ in.	50 min.	70–90
A633/A633M	C and D	Plates	Thickness > $2\frac{1}{2}$ in. and ≤ 4 in.	46 min.	65–85
A633/A633M	E	Plates	Thickness ≤ 4 in.	60 min.	80–100
A633/A633M	E	Plates	Thickness > 4 in. and ≤ 6 in.	55 min.	75–95
A709/A709M	36	Plates, shapes, and bars	Plates and bars ≤ 4 in. and shapes [for shapes, see Note (2)]	36 min.	58–80
A709/A709M	50	Plates, shapes, and bars	Plates and bars ≤ 4 in. and shapes	50 min.	65 min.
A709/A709M	50W	Plates, shapes, and bars	Plates and bars ≤ 4 in. and shapes	50 min.	70 min.
A737/A737M	B	Plates	Thickness ≤ $2\frac{1}{2}$ in.	50 min.	70–90
A737/A737M	C	Plates	Thickness ≤ $2\frac{1}{2}$ in.	60 min.	80–100
A913/A913M	50	Shapes	All shapes	50 min.	65 min.

Table CM-2.1.5.1-1
Acceptable Materials and Reference Properties for Structural Components (Cont'd)

ASTM Specification	Grade or Class	Form	Size [Note (1)]	Yield Strength, ksi	Tensile Strength, ksi
A913/A913M	60	Shapes	All shapes	60 min.	75 min.
A913/A913M	65	Shapes	All shapes	65 min.	80 min.
A913/A913M	70	Shapes	All shapes	70 min.	90 min.
A992/A992M [Note (4)]	...	Shapes	All shapes [Note (5)]	50–65	65 min.
A992/A992M [Note (4)]	...	Patented shape track	...	...	...

GENERAL NOTE: The data in this table are from the Annual Book of ASTM Standards (2007).

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 exception from fracture toughness requirements in Table CM-2.1.5.1-2, Note (3) does not apply to this material.
(4) Mechanical properties, standard sizes, design, and selection criteria for patented shape track are under the auspices of the individual manufacturers. Patented shape track is comprised of an upper T-section (compression member) of standard structural steel and a lower load-carrying T-section (tension member) of high-strength alloy steel. The two sections are welded continuously from both sides, web-to-web. Patented shape track is also used for crane bridge girders and jib crane booms with under-running trolleys or hoists with integral trolleys.
(5) The yield strength to tensile strength ratio shall not exceed 0.85.

Table CM-2.1.5.1-2
Required Inspection or Tests

Items	Material Test Reports	Certificate of Conformance From Item Manufacturer	NDE of Welds [Note (1)]	UT [Note (2)]	Surface MT or PT	Impact Test [Note (3)]	Weld Filler Material Certificate of Conformance Typical Value	Welder Certifications
Primary load-bearing structural welds	...	...	X	...	...	...	X	X
Fastener material for structural interconnections (including seismic restraints and safety lugs)	X	X	...	...	...	...	...	...
Crane or monorail structure	X	...	...	...	...	X	...	...
Bridge seismic restraints	X	...	X	...	...	X	X	X
Safety lugs	X	...	X	...	...	X	X	X
Hinges or pins on jib cranes [Note (4)]	X	...	...	X	X	...	...	...
Tension rods for jibs or monorails [Note (4)]	X	...	...	X	X	...	...	...

Legend:
MT = magnetic particle testing
NDE = nondestructive examination
PT = dye penetrant testing
UT = ultrasonic testing

NOTES:
(1) See para. CM-7.1.2.1.1.
(2) See para. CM-7.1.2.1.3.
(3) Impact testing required for materials greater than $^5/_8$ in. thickness. See para. CM-7.1.2.1.2.
(4) If the item is designed with double the design margin, material test reports are not required.

Table CM-2.1.6.1.1-1
Allowable Stresses
(Members Not Controlled by Buckling)

Loading Condition (All Expressed in Terms of σ_y)	Stress Type			
	Tension	Compression [Note (1)]	Shear	Bearing
Principal	0.60	0.60	0.36	0.80
Additional	0.66	0.66	0.40	0.90
Extraordinary	0.75	0.75	0.45	1.00
Extreme	0.90	0.90	0.50	n/a

NOTE: (1) The allowable stress is for a gross compact section. See para. CM-2.1.6.1.2 for members controlled by buckling.

CM-2.1.5.4.2.2 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 requirement for non-high-strength bolts specified in the "Specification for Structural Steel for Buildings — Allowable Stress Design and Plastic Design" included in the AISC Manual of Steel Construction: Allowable Stress Design. All bolts shall be torqued to a pretension load on the bolt of 60% to 70% of the minimum yield strength for the bolt materials. Standard holes shall have a maximum diameter $^1/_{16}$ in. in excess of the nominal bolt diameter. Holes for alignment (bound) bolts shall be reamed to close tolerances as required.

CM-2.1.5.4.2.3 Gauge and Edge Distances. The minimum gauge between centers of bolt holes and minimum and maximum edge distances from the center of a bolt hole to any edge shall be as stipulated in the "Specification for Structural Steel for Buildings — Allowable Stress Design and Plastic Design" included in the AISC Manual of Steel Construction: Allowable Stress Design.

CM-2.1.5.4.2.4 Field Connections. All field connections of structural components shall be bolted unless otherwise approved by the owner. The manufacturer shall provide sufficient information on drawings or in installation manuals on the requirements for all field connections.

CM-2.1.6 Design Criteria

CM-2.1.6.1 Basic Allowable Stresses for Structural Steel Members

CM-2.1.6.1.1 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 the values in Table CM-2.1.6.1.1-1.

CM-2.1.6.1.2 Compression Members Controlled by Buckling

(a) For compression members with an equivalent slenderness ratio

$$\frac{kl}{r} < C_c \qquad \text{(CM-2-12)}$$

where

C_c = column slenderness ratio separating elastic and inelastic buckling
$= \sqrt{\dfrac{2\pi^2 E}{\sigma_y}}$
E = modulus of elasticity, psi
k = effective length factor
l = unbraced length of compression member, in.
r = radius of gyration of member, in.
σ = yield point, psi

The allowable axial compression stress, σ_a, is

$$\sigma_a = \left[1 - \frac{\left(\frac{kl}{r}\right)^2}{2{C_c}^2}\right]\left(\frac{\sigma_y}{\mathrm{DF}}\right) \qquad \text{(CM-2-13)}$$

where

DF = design factor

The required design factor shall be equal to

$$\mathrm{DF} = N\left\{\frac{5}{3} + \frac{3}{8}\left[\frac{\left(\frac{kl}{r}\right)}{C_c}\right] - \frac{1}{8}\left[\frac{\left(\frac{kl}{r}\right)}{C_c}\right]^3\right\} \qquad \text{(CM-2-14)}$$

where

N = modifying coefficient for each loading condition. Values of N can be found in Table CM-2.1.6.1.2-1.

(b) For compression members with an equivalent slenderness ratio

$$\frac{kl}{r} \geq C_c \qquad \text{(CM-2-15)}$$

The allowable axial compression stress shall not exceed the value

$$\sigma_a = \frac{12\pi^2 E}{23N\left(\frac{kl}{r}\right)^2} \qquad \text{(CM-2-16)}$$

Table CM-2.1.6.1.2-1
Modifying Coefficient, *N*

Loading Condition	Modifying Coefficient, *N*
Principal	1.2
Additional	1.2
Extraordinary	0.9
Extreme	1.67

CM-2.1.6.1.3 Bending Stress. The allowable bending stress for each loading condition shall be determined by dividing the appropriate value from the AISC Manual of Steel Construction: Allowable Stress Design, Part 5, Chapter F, by 1.12N (where N is defined in Table CM-2.1.6.1.2-1).

CM-2.1.6.1.4 Welds. Basic allowable stresses in welds shall be as specified in AWS D14.1. Allowable stresses for all types of welds may be increased for extraordinary load combinations by a factor of 1.33 and increased for extreme load combinations by a factor of 1.50.

CM-2.1.6.1.5 Bolts

(a) *ASTM A325 or ASTM A490 Bolts.* Allowable working stresses for operational (principal load case) or construction loads (additional load case) shall be in accordance with the "Specification for Structural Joints Using ASTM A325 and ASTM A490 Bolts" included in the AISC Manual of Steel Construction: Allowable Stress Design. 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 extraordinary loadings and 1.50 for extreme loadings.

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

(b) *Bolts Other Than ASTM A325 or ASTM A490.* Allowable stresses shall be in accordance with Table CM-2.1.6.1.5-1.

Table CM-2.1.6.1.5-1
Bolt Allowable Stresses

Loading Condition (Expressed in Terms of Ultimate Strength)	Stress Type	
	Tension	Shear
Principal	0.33	0.17
Additional	0.33	0.17
Extraordinary	0.44	0.23
Extreme	0.50	0.26

CM-2.1.6.2 Combined Stresses

CM-2.1.6.2.1 Axial Compression and Bending. Members subjected to both axial compression and bending stresses shall satisfy the following requirements:

$$\frac{\sigma}{\sigma_a} + \frac{C_{mx}\sigma_{bx}}{\left(1 - \frac{\sigma}{\sigma_{ex}}\right)\sigma_{abx}} + \frac{C_{my}\sigma_{by}}{\left(1 - \frac{\sigma}{\sigma_{ey}}\right)\sigma_{aby}} \leq 1.0 \quad \text{(CM-2-17)}$$

$$\frac{\sigma}{\sigma_a} + \frac{\sigma_{bx}}{\sigma_{abx}} + \frac{\sigma_{by}}{\sigma_{aby}} \leq 1.0 \quad \text{(CM-2-18)}$$

When $(\sigma/\sigma_a) \leq 0.15$, the following equation may be used in lieu of eqs. (CM-2-17) and (CM-2-18):

$$\frac{\sigma}{\sigma_a} + \frac{\sigma_{bx}}{\sigma_{abx}} + \frac{\sigma_{by}}{\sigma_{aby}} \leq 1.0 \quad \text{(CM-2-19)}$$

In eqs. (CM-2-17) through (CM-2-19), 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

C_m = coefficient whose value shall be given in (a) through (c)
σ_a = allowable axial stress (see para. CM-2.1.6.1.1)
σ_{ab} = allowable bending stress (see para. CM-2.1.6.1.1)

It is to be noted that

σ_a = σ_{ab} in paras. CM-2.1.6.1.1 and CM-2.1.6.1.2
σ_{ab} = σ_a as given in para. CM-2.1.6.1.1 only

$$\sigma_e = \frac{12\pi^2 E}{23N\left(\frac{kl}{r}\right)^2} \quad \text{(CM-2-20)}$$

where

E = modulus of elasticity, psi
k = effective length factor in the plane of bending
l = actual unbraced length in the plane of bending, in.
N = loading condition factor given in Table CM-2.1.6.1.2-1
r = corresponding radius of gyration, in.
σ = computed axial stress, psi
σ_b = computed compressive bending stress at the section under consideration, psi

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

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

$$C_m = 0.6 - 0.4\left(\frac{M_1}{M_2}\right) \geq 0.4 \quad \text{(CM-2-21)}$$

where

M_1/M_2 = ratio of the smaller to larger moments at the ends of the 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 analysis; however, in lieu of such analysis, the following values may be used:

(1) For members whose ends are restrained against rotation in the plane of bending, C_m = 0.85.

(2) For members whose ends are unrestrained against rotation in the plane of bending, C_m = 1.0.

CM-2.1.6.2.2 Axial Tension and Bending. Members subject to both axial tension and bending stresses shall be proportioned at all points along their length to satisfy the following equation:

$$\frac{\sigma_t}{\sigma_{at}} + \frac{\sigma_{bx}}{\sigma_{abx}} + \frac{\sigma_{by}}{\sigma_{aby}} \leq 1.0 \quad \text{(CM-2-22)}$$

where

σ_{abx} = allowable bending stress about the member's x-axis, psi

σ_{aby} = allowable bending stress about the member's y-axis, psi

σ_{at} = allowable axial tension stress as determined from Table CM-2.1.6.1.1-1, psi

σ_{bx} = computed bending stress about the member's x-axis, psi

σ_{by} = computed bending stress about the member's y-axis, psi

σ_t = computed axial tension stress, psi

The computed bending compressive stress arising from an independent load source relative to the axial tension described above shall not exceed the applicable value required in para. CM-2.1.6.1.3.

CM-2.1.6.2.3 Local Bending of Flanges due to Wheel Loads

(a) Each wheel load shall be considered as a concentrated load applied at the center of the wheel contact area with the flange. See Figure CM-2.1.6.2.3-1.

(b) Local flange bending stresses, σ, in the lateral (x) and longitudinal (y) directions at certain critical points may be calculated using eqs. (CM-2-23) through (CM-2-41). Other suitable formulas or analysis may be adopted in lieu of eqs. (CM-2-23) through (CM-2-41) to address the local flange bending stresses.

(1) Underside of flange at flange-to-web transition, point 0

$$\sigma_{x0} = C_{x0}\frac{P}{{t_a}^2} \quad \text{(CM-2-23)}$$

$$\sigma_{y0} = C_{y0}\frac{P}{{t_a}^2} \quad \text{(CM-2-24)}$$

(2) Underside of flange directly beneath wheel contact point, point 1

$$\sigma_{x1} = C_{x1}\frac{P}{{t_a}^2} \quad \text{(CM-2-25)}$$

$$\sigma_{y1} = C_{y1}\frac{P}{{t_a}^2} \quad \text{(CM-2-26)}$$

(3) Topside of flange at flange-to-web transition, point 2

$$\sigma_{x2} = -\sigma_{x0} \quad \text{(CM-2-27)}$$

$$\sigma_{y2} = -\sigma_{y0} \quad \text{(CM-2-28)}$$

(4) For tapered flange sections (see Figure CM-2.1.6.2.3-2)

$$C_{x0} = -1.096 + 1.095\lambda + 0.192e^{-6.0\lambda} \quad \text{(CM-2-29)}$$

$$C_{x1} = 3.965 - 4.835\lambda - 3.965e^{-2.675\lambda} \quad \text{(CM-2-30)}$$

$$C_{y0} = -0.981 - 1.479\lambda + 1.120e^{1.322\lambda} \quad \text{(CM-2-31)}$$

$$C_{y1} = 1.810 - 1.150\lambda + 1.060e^{-7.70\lambda} \quad \text{(CM-2-32)}$$

$$t_a = t_f - \left(\frac{b}{24}\right) + \left(\frac{a}{6}\right) \quad \text{(CM-2-33)}$$

for standard "S" section, where

t_f = published flange thickness for standard "S" section, in.

(5) For parallel flange (see Figures CM-2.1.6.2.3-3 and CM-2.1.6.2.3-4)

$$C_{x0} = -2.110 + 1.977\lambda + 0.0076e^{6.53\lambda} \quad \text{(CM-2-34)}$$

$$C_{x1} = 10.108 - 7.408\lambda - 10.108e^{-1.364\lambda} \quad \text{(CM-2-35)}$$

$$C_{y0} = 0.050 - 0.580\lambda + 0.148e^{3.015\lambda} \quad \text{(CM-2-36)}$$

$$C_{y1} = 2.230 - 1.490\lambda + 1.390e^{-18.33\lambda} \quad \text{(CM-2-37)}$$

(6) For single-web symmetrical sections (see Figures CM-2.1.6.2.3-2 and CM-2.1.6.2.3-3)

$$\lambda = \frac{2a}{b - t_w} \quad \text{(CM-2-38)}$$

(7) For other cases (see Figure CM-2.1.6.2.3-4)

$$\lambda = \frac{a}{b' - \left(\frac{t_w}{2}\right)} \quad \text{(CM-2-39)}$$

where

a = distance from edge of flange to point of wheel load application for center of wheel contact, in.

b = overall length of flange (from edge of flange to edge of flange), in.

b' = distance from centerline of web to edge of flange, in.

C_x = coefficient in the x direction for a given location

C_y = coefficient in the y direction for a given location

P = load per wheel including HLF, lb.

t_a = flange thickness at point of load application, in.

t_f = published flange thickness for standard "S" section, in.

t_w = web thickness, in.

λ = ratio of the load with respect to the free end of the flange

NOTE: If $\frac{1}{2}b - a$ < centerline distance between adjacent wheels, then the load P is equal to the maximum single wheel load without considering the effect of the adjacent wheel. Conversely, if $\frac{1}{2}b - a \geq$ centerline distance between adjacent wheels, then the loading of the two adjacent wheels shall be combined into a single load.

(c) The localized stresses due to local bending effects imposed by wheel loads calculated at points 0 and 1 are to be combined with the stresses due to case 2 loading specified in para. CM-2.1.2.

When calculating the combined stress, the flange bending stresses shall be diminished to 75% of the value calculated per (b) above.

The combined stress value, σ_t, obtained by the method prescribed in (g) shall not exceed the allowable case 2 stress level of $0.66\sigma_y$, where σ_y = yield strength of the material.

(d) In the case of welded plate girders only, the localized stresses on the top side of the flange at the flange-to-web transition (point 2) shall be combined with the stresses due to the case 2 loading specified in para. CM-2.1.2.

The combined stress value, σ_v, in the weld at point 2 obtained by the method prescribed in (g) below shall not exceed the allowable weld stress specified in para. CM-2.1.5.4.1, nor shall the stress range in the weld exceed the value specified in Table CM-2.1.6.4.1-1 for joint category E.

(e) The local flange bending criteria per para. CM-2.1.6.2.3 shall be met in addition to the general criteria of paras. CM-2.1.2 and CM-2.1.6.1.

(f) At transfer points, consideration should be given to lower flange stresses that are not calculable by the formulae presented in para. CM-2.1.6.2.3.

(g) Where a state of combined plane stresses exists, the reference stress, σ_t, can be calculated from the following equation:

$$\sigma_t = \sqrt{{\sigma_x}^2 + {\sigma_y}^2 - \sigma_x\sigma_y + 3{\tau_{xy}}^2} \leq \sigma_{\text{all}} \quad \text{(CM-2-40)}$$

where

σ_{all} = allowable stress, psi

σ_x = normal stress in the x direction, psi

σ_y = normal stress in the y direction, psi

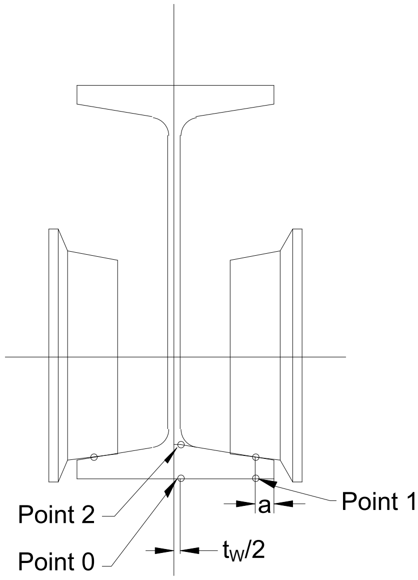
τ_{xy} = shear stress in plane, psi

For welds, the maximum combined stress, σ_v, shall be calculated as follows:

$$\sigma_v = \frac{1}{2}(\sigma_x + \sigma_y) \pm \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4{\tau_{xy}}^2} \leq \sigma_{\text{all}} \quad \text{(CM-2-41)}$$

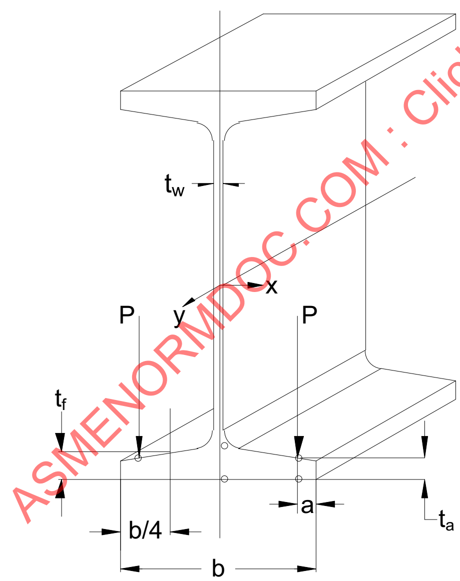
See Nonmandatory Appendix A, subsection A-2 for a lower flange bending calculation example.

Figure CM-2.1.6.2.3-1
Local Bending of Flanges due to Wheel Loads



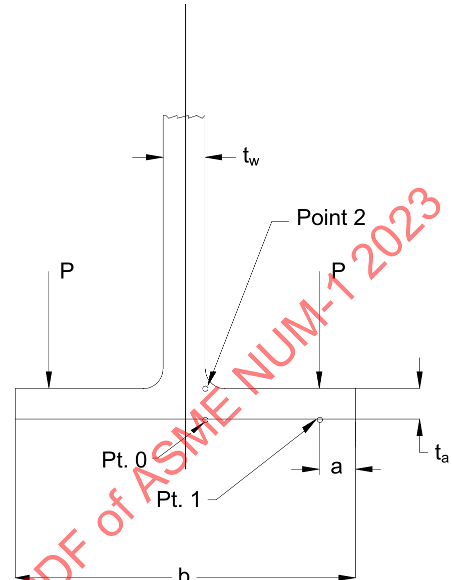
GENERAL NOTE: Figure 3.3.2.6-1 from CMAA 74-2020 is reprinted courtesy of the Crane Manufacturers Association of America.

Figure CM-2.1.6.2.3-2
Local Loading on Tapered Flanges of a Standard S-Shaped Beam



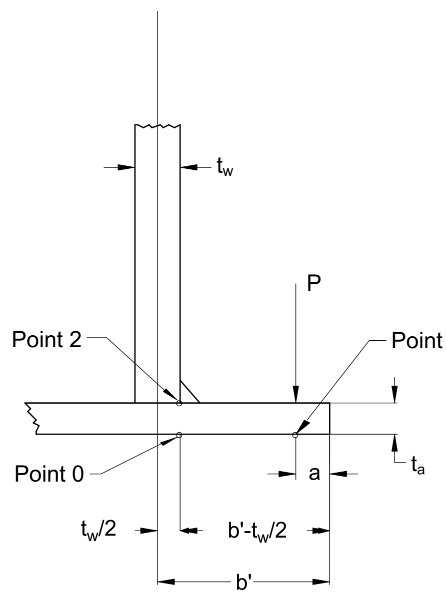
GENERAL NOTE: Figure 3.3.2.6-2 from CMAA 74-2020 is reprinted courtesy of the Crane Manufacturers Association of America.

Figure CM-2.1.6.2.3-3
Local Loading on Parallel Flanges of a Wide Flange W-Shaped Beam



GENERAL NOTE: Figure 3.3.2.6-3 from CMAA 74-2020 is reprinted courtesy of the Crane Manufacturers Association of America.

Figure CM-2.1.6.2.3-4
Local Loading on Parallel Flanges of the Lower Chord of a Box Girder



GENERAL NOTE: Figure 3.3.2.6-4 from CMAA 74-2020 is reprinted courtesy of the Crane Manufacturers Association of America.

Table CM-2.1.6.2.4-1
Bolt Shear and Tension Factor, *R*

Loading Condition	Bolt Shear and Tension Factor, *R*
Principal	1
Additional	1
Extraordinary	1.33
Extreme	1.50

CM-2.1.6.2.4 Shear and Tension of Bolts

(a) Bolts subject to combined shear and tension shall be so proportioned that the tension stress, in pounds per square inch, produced by forces applied to the connected parts, shall not exceed the allowable tension value, σ_{at}.

(1) For A325 bolts in bearing-type joints

$$\sigma_{at} = 55{,}000R - 1.8\tau \le 44{,}000R \quad \text{(CM-2-42)}$$

(2) For A490 bolts in bearing-type joints

$$\sigma_{at} = 68{,}000R - 1.8\tau \le 54{,}000R \quad \text{(CM-2-43)}$$

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

$$\sigma_{at} = 0.6\sigma_y R - 1.6\tau \quad \text{(CM-2-44)}$$

where

R = bolt shear and tension factor given in Table CM-2.1.6.2.4-1
σ_y = yield stress, psi (the proof stress may be used)
τ = shear stress produced by the same forces applied to the connected parts, psi. The shear stress shall not exceed the value for the shear given in para. CM-2.1.6.1.5.

(b) For bolts used in friction-type joints, the shear stress, τ_a, allowed in para. CM-2.1.6.1.5 shall be reduced so that

(1) for A325 bolts

$$\tau_a \le 15{,}000\left(1 - \frac{\sigma_\tau A_b}{T_b}\right) \quad \text{(CM-2-45)}$$

(2) for A490 bolts in bearing-type joints

$$\tau_a \le 20{,}000\left(1 - \frac{\sigma_\tau A_b}{T_b}\right) \quad \text{(CM-2-46)}$$

where

A_b = tensile stress area, in.^{2}
T_b = specified pre-tension load of the bolt, lb
σ_τ = average tensile stress due to a direct load applied to all the bolts in a connection, psi

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

CM-2.1.6.2.5 Shear and Bending Stresses. The maximum combined shear stress due to shear, bending, and direct stresses shall not exceed the allowable values for shear as given in para. CM-2.1.6.1.1.

CM-2.1.6.3 Buckling

CM-2.1.6.3.1 Local Buckling or Crippling of Flat Plates. The structural design of the crane to avoid local buckling of plates shall conform to ASME NOG-1, paras. 4331 through 4332.1.

CM-2.1.6.3.2 Proportion for Fabricated Box Girders. The ratio of l/h shall not exceed 25, the ratio of l/b_1 shall not exceed 60, and the ratio of b/t shall not exceed

$$\sqrt{\frac{(2.62 \times 10^7)K_\sigma}{\sigma_p} \times \frac{2}{\text{DFB}}} \quad \text{(CM-2-47)}$$

For A36 steel, eq. (CM-2-47) is equal to 30.99 {the square root of $[K_\sigma/(2/\text{DFB})]$} where

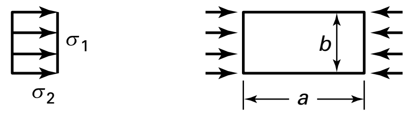
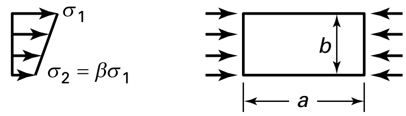
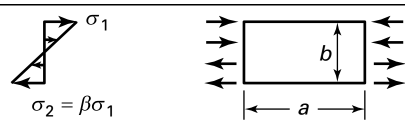
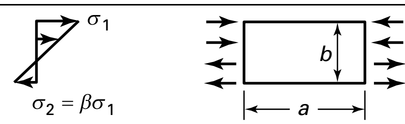
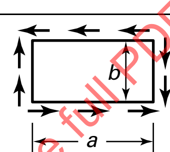
b = unsupported plate width between longitudinal stiffeners, webs, or cover plate, in.
b_1 = distance between the web plates at the compression flange, in.
d = depth of the girder, in.
DFB = design factor for buckling based on operating conditions (see Table CM-2.1.6.3.2-1)
h = depth of web, in.
K_σ = buckling coefficient compression (see Table CM-2.1.6.3.2-2)
l = span, in.
t = thickness of web plate, in.
σ_p = proportional limit (assumed at $\sigma_y/1.32$)

Table CM-2.1.6.3.2-1
Design Factor for Buckling, DFB

Loading Condition	DFB [Note (1)]
Principal	2 + 0.3(β − 1) ≥ 1.40
Additional	2 + 0.3(β − 1) ≥ 1.40
Extraordinary	1.5 + 0.125(β − 1) ≥ 1.25
Extreme	1.35 + 0.075(β − 1) ≥ 1.20

NOTE: (1) β = stress ratio.

Table CM-2.1.6.3.2-2
Value of the Buckling Coefficients, K_σ and K_τ, for Plates Supported at Their Four Edges

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

GENERAL NOTE: The definitions of K_σ and K_τ are in the 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.

CM-2.1.6.3.3 Spacing of Transverse Stiffener. The spacing of the transverse stiffeners, a, in inches, shall not exceed the amount given by eq. (CM-2-4) nor shall it exceed 72 in. or the depth of the web, h, whichever is greater.

$$a = \frac{11{,}068t}{\sqrt{\tau C}} \quad \text{(CM-2-48)}$$

where

C = spacing coefficient (see Table CM-2.1.6.3.3-1)
t = thickness of the web plate, in.
τ = shear stress in plate, psi

CM-2.1.6.3.4 Stiffness of Longitudinal and Transverse Stiffeners. The required stiffness of the longitudinal stiffener and the transverse stiffeners shall be in accordance with CMAA 74.

CM-2.1.6.3.5 Girder Deflection. The total vertical deflection of the girder during operational loading for the rated live load plus the trolley, $P_{ln} + P_{dt}$, not including impact or dead load of the girder, shall not exceed $1/_{1,000}$ of the span.

The total vertical deflection of the girder during constructional loading for the construction load plus the trolley, $P_{cn} + P_{dt}$, not including impact or dead load of the girder, shall not exceed $1/_{600}$ of the span.

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.

CM-2.1.6.3.6 Girder Camber. Girders shall be cambered an amount equal to the dead load deflection, plus one-half of the deflection caused by the live load, plus trolley: [camber = $\Delta(P_{db}) + 0.5(P_{ln} + P_{dt})$].

CM-2.1.6.4 Fatigue Requirements. If the owner determines that more than 20,000 full-load cycles are required, the owner shall specify the cycles and load class per para. CM-2.1.6.4.1. The allowable stresses for the appropriate service level shall be used but shall not exceed the basic allowable operating stresses specified in para. CM-2.1.6.1.

Table CM-2.1.6.3.3-1
Spacing Coefficient, *C*

Loading Condition	Spacing Coefficient, *C*
Operating	1
Construction	1
Severe environment	0.75
Extreme	0.6

CM-2.1.6.4.1 Allowable Stress Range, Repeated Loads. Members and fasteners subject to repeated loads shall be designed so that the stress range (maximum stress minus minimum stress) does not exceed allowable values for various categories listed in Table CM-2.1.6.4.1-1. The minimum stress is considered negative if it is opposite in sign to the maximum stress. The categories are described in Table CM-2.1.6.4.1-2, with joint configuration illustrations shown in Figure CM-2.1.6.4.1-1. The allowable stress range shall be based on the condition best approximated by the description and illustration.

CM-2.1.6.5 Hardness. The minimum Brinell hardness (BHN) of the lower load-carrying (tension) flange shall be 195 for patented track systems. For A36 material, the normal hardness produced by normal mill processing shall be sufficient.

CM-2.1.6.6 Stability. The crane shall be stable under all loading conditions. A factor of safety of 1.5 shall be provided against the combination of loads producing maximum overturning forces.

CM-2.1.7 Component Design

CM-2.1.7.1 Footwalks, Handrails, Platforms, Stairs, and Ladders

CM-2.1.7.1.1 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 ASME B30.17.

CM-2.1.7.1.2 Design. Footwalks, handrails, platforms, stairs, and ladders shall be designed for the appropriate dead load and the live loads as specified in ASME B30.17. Structural design shall be in accordance with para. CM-2.1.6.

CM-2.1.7.2 Operator's Cab (When Specified)

CM-2.1.7.2.1 General

(a) The general arrangement of the cab and the location of the control and protective equipment shall be such that all operating control devices are within convenient reach of the operator when facing the area to be served by the load block or when facing the direction of travel of the cab. The operator's cab shall be open type for indoor service unless otherwise specified.

(b) The cab shall be clear of all fixed structures within its area of possible movement. Clearances shall be in accordance with the latest edition of ASME B30.17. The cab shall be located so as not to interfere with the hook approach.

(c) The arrangement of equipment in the cab should be approved by the owner.

(d) Cabs shall be designed for maximum operator visibility. The arrangement of the cab should allow the operator a full view of the load block in all positions. A visibility diagram shall be furnished to the owner for approval when requested.

(e) The operator's cab shall have a clear height, with equipment installed, of not less than 7 ft, except where dimensional interferences or other design considerations require the use of a smaller cab. Cab heights of less than 7 ft shall be approved by the owner, and in no case shall be less than 5 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.

(f) There shall be means of egress from cab-operated cranes to permit departure under emergency conditions from any cab location.

CM-2.1.7.2.2 Materials. Materials for construction of the operator's cab shall meet the requirements of para. CM-2.1.5.

CM-2.1.7.2.3 Design. The operator's cab shall be designed for dead and live loads as specified by the owner. Structural design shall be in accordance with para. CM-2.1.6.

CM-2.1.7.2.4 Construction

CM-2.1.7.2.4.1 General. Cabs shall be constructed in accordance with ASME B30.17.

CM-2.1.7.2.4.2 Enclosed Cabs. Enclosed cabs shall have watertight plate roofs that slope to the rear; sliding, hinged, or drop windows on the three sides; and sliding or hinged doors. Steel plates for enclosing sides, when used, shall not be less than $\frac{1}{8}$ in. thick. The window sash shall be equipped with clear, shatterproof glass installed from the inside so that if the glass is dislodged, it will fall into the cab.

Table CM-2.1.6.4.1-1
Allowable Stress Ranges

Service Class	Allowable Stress Range, $F_{s\sigma}$, kips/in.^{2}, by Joint Category [Notes (1), (2)] A	B	C	D	E	F
A	63	49	35	28	22	15
B	50	39	28	22	18	14
C	37	29	21	16	13	12
D	31	24	17	13	11	11

NOTES:
(1) Allowable stress ranges from CMAA 74.
(2) Stress range values are independent of material yield stress.

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 the operator from catching fingers or toes when operating the windows. Drop windows shall be counterweighted.

CM-2.1.7.2.4.3 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 toeplate. Where the top rail or top panel interferes with the operator's vision, it may be lowered if the owner approves.

CM-2.2 ADDITIONAL REQUIREMENTS SPECIFIC TO UNDERHUNG CRANES

CM-2.2.1 Allowable Deflections and Cambers

CM-2.2.1.1 Miscellaneous Structure Deflection. Deflections of components such as end ties, end trucks, trolley load bars, and auxiliary beams shall not impair the functions for which they were designed nor cause any attachments to the crane to become dislodged or leave the crane.

CM-2.2.1.2 Girder Deflection. The maximum vertical deflection of the girder produced by the bridge dead load, trolley dead load (including hoist dead weight), and design-rated load shall not exceed $\frac{1}{600}$ of the span. Impact need not be considered in determining deflection. For interlocking cranes, the deflection shall not exceed $\frac{1}{1,000}$ of the span.

CM-2.2.1.3 Girder Camber. Where girders are cambered, the recommended amount of camber is equal to the sum of the bridge dead load deflection, one-half of the deflection caused by the trolley dead load (including hoist dead weight), and one-half of the deflection caused by the design-rated load. Girder camber and deflection shall be considered when determining vertical clearances.

CM-2.2.2 Component Design

CM-2.2.2.1 Girders, Beams, or Tracks. Girders may be standard rolled beams, patented shape track, or plate girders. Where necessary, auxiliary girders shall be used to support overhanging loads to minimize torsional moments on and lateral deflections of the girder. The analysis required for girders shall be in accordance with subsection CM-2.1. For spans longer than 16 ft, the ratio of span to top-flange width shall not exceed 60:1.

CM-2.2.2.2 End Trucks. The crane bridge shall be carried on end trucks designed to carry the rated loads when lifted at one end of the crane bridge (closest approach). Load combinations and basic allowable stresses shall be in accordance with paras. CM-2.1.2 and CM-2.1.6.1. The wheelbase of the outermost wheels shall be one-eighth of the span or greater.

End trucks may be of the rotating-axle or fixed-axle type. Provisions shall be made to prevent a drop of the crane not more than 1 in. in the case of axle failure. When appropriate, equalizer bridge trucks shall be incorporated to promote sharing of the bridge wheel loads. Equalizer pins shall be provided between the equalizer truck and the equalizer beam or between the equalizer truck and the rigid bridge structure as appropriate to the design. A rail sweep shall be provided in front of each outside wheel. End trucks shall meet the requirements of the applicable paragraphs of subsection CM-2.1.

CM-2.3 ADDITIONAL REQUIREMENTS SPECIFIC TO TOP-RUNNING BRIDGE AND GANTRY CRANES

CM-2.3.1 Allowable Deflections and Cambers

CM-2.3.1.1 Structure Deflection. Deflections of components such as end ties, end trucks, trolley load bars, and auxiliary beams shall not impair the functions for which they were designed or cause any attachments of the crane to become dislodged or leave the crane.

CM-2.3.1.2 Girder Deflection. The maximum vertical deflection of the girder produced by the bridge dead load, trolley dead load (including hoist dead weight), and the design-rated load shall not exceed $\frac{1}{600}$ of the span. Vertical inertia forces need not be considered when determining deflection. For interlocking cranes, the deflection shall not exceed $\frac{1}{1,000}$ of the span.

CM-2.3.1.3 Girder Camber. Where girders are cambered, the recommended amount is equal to the sum of the bridge dead load deflection, one-half of the deflection caused by the trolley dead load (including hoist dead weight), and one-half of the deflection caused by the design-rated load. Girder camber and deflection shall be considered when determining vertical clearance.

Table CM-2.1.6.4.1-2
Fatigue Stress Provisions — Tension or Reversal Stresses

General Condition	Situation	Joint Category	Example of a Situation [Note (1)]	Type of Stress [Note (2)]
Plain material	Base metal with rolled or cleaned surfaces; oxygen-cut edges with ANSI smoothness of 1,000 or less	A	1, 2	T or Rev
Built-up members	Base metal and weld metal in members without attachments, built up; of plates or shapes connected by continuous complete or partial joint penetration groove welds or by continuous fillet welds parallel to the direction of applied stress	B	3, 4, 5, 7	T or Rev
	Calculated flexural stress at toe of transverse stiffener welds on girder webs or flanges	C	6	T or Rev
	Base metal at end of partial-length welded cover plates having square or tapered ends, with or without welds across the ends	E	7	T or Rev
Groove welds	Base metal and weld metal at complete joint penetration groove-welded splices of rolled and welded sections having similar profiles when welds are ground and weld soundness established by UT or RT examination	B	8, 9	T or Rev
	Base metal and weld metal in or adjacent to complete joint penetration groove-welded splices at transitions in width or thickness, with welds ground to provide slopes no steeper than 1 to $2\frac{1}{2}$ and weld soundness established by UT or RT examination	B	10, 11	T or Rev
	Weld metal or partial penetration transverse groove welds based on effective throat area of the weld or welds	F	17	T or Rev
Groove welds	Base metal and weld metal in or adjacent to complete joint penetration groove-welded splices either not requiring transition, or, when required with transitions, having slopes no greater than 1 to $2\frac{1}{2}$ and when in either case reinforcement is not removed and weld soundness is established by UT or RT examination	C	8, 9, 10, 11	T or Rev
	Base metal and weld metal at complete joint penetration groove-welded splices of sections having similar profiles or at transitions in thickness to provide slopes no steeper than 1 to $2\frac{1}{2}$ with permanent backing bar parallel to the direction of stress when welds are ground and weld soundness established by UT or RT examination. Backing bar shall be continuous, and, if spliced, shall be joined by a full-penetration butt weld. Backing bar shall be connected to parent metal by continuous welds along both edges, except in regions of compression stress, where intermittent welds may be used	B	19, 20	...
Groove-welded connections	Base metal at details of any length attached by groove welds subjected to transverse loading or longitudinal loading, or both, when weld soundness transverse to the direction of stress is established by UT or RT examination and the detail embodies a transition radius, *R*, with the weld termination ground when			
	(a) for longitudinal loading			
	$R \geq 24$ in.	B	13	...
	24 in. $> R \geq 6$ in.	C	13	...
	6 in. $> R \geq 2$ in.	D	13	...
	2 in. $> R \geq 0$	E	12, 13	...
	(b) for transverse loading, materials having equal or unequal thickness, slope, welds ground, web connections excluded			
	$R \geq 24$ in.	B	13	T or Rev
	24 in. $> R \geq 6$ in.	C	13	T or Rev
	6 in. $> R \geq 2$ in.	D	13	T or Rev
	2 in. $> R \geq 0$	E	12, 13	T or Rev

Table CM-2.1.6.4.1-2
Fatigue Stress Provisions — Tension or Reversal Stresses (Cont'd)

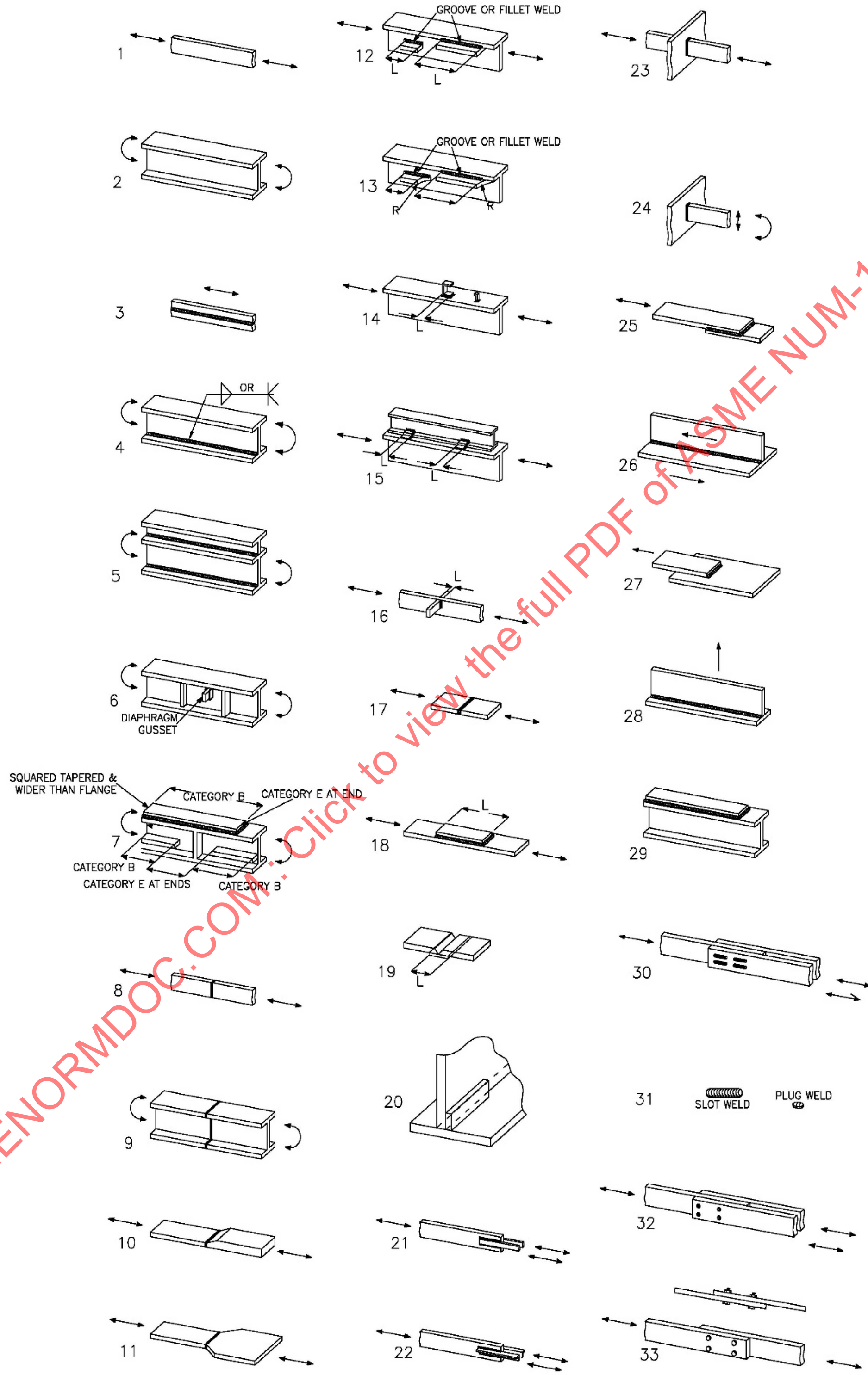
General Condition	Situation	Joint Category	Example of a Situation [Note (1)]	Type of Stress [Note (2)]
Groove-welded connections (cont'd)	(c) for transverse loading, materials having equal thickness, no ground, web connections excluded			
	$R \geq 24$ in.	C	13	T or Rev
	24 in. > $R \geq 6$ in.	C	13	T or Rev
	6 in. > $R \geq 2$ in.	D	13	T or Rev
	2 in. > $R \geq 0$	E	12, 13	T or Rev
	(d) for transverse loading, materials having unequal thickness, not sloped or ground, including web connections			
	$R \geq 24$ in.	E	13	T or Rev
	24 in. > $R \geq 6$ in.	E	13	T or Rev
	6 in. > $R \geq 2$ in.	E	13	T or Rev
	2 in. > $R \geq 0$	E	12, 13	T or Rev
Groove-welded or fillet-welded connections	Base metal at details attached by groove or fillet welds subject to longitudinal loading where the detail embodies a transition radius, R, less than 2 in., and when the detail length, L, parallel to the line of stress is			
	$L \leq 2$ in.	C	12, 14, 15, 16, 18	T or Rev
	2 in. < $L \leq 4$ in.	D	12, 18	T or Rev
	L > 4 in.	E	12, 18	T or Rev
Fillet-welded connections	Base metal at details attached by fillet welds or partial penetration groove welds parallel to the direction of stress, regardless of length, when the detail embodies a transition radius, R, 2 in. or greater and with the weld termination ground. When			
	$R \geq 24$ in.	B	13	T or Rev
	24 in. > R > 6 in.	C	13	T or Rev
	6 in. ≥ R > 2 in.	D	13	T or Rev
	Base metal at junction of axially loaded members with fillet-welded end connections. Welds shall be disposed about the axis of the member to balance weld stresses	E	21, 22, 23	T or Rev
Fillet welds	Shear stress on throat of fillet welds	F	21, 22, 23, 24, 25, 26, 27, 28	S
	Base metal at intermittent welds attaching transverse stiffeners and stud-type shear connectors	C	7, 14	T or Rev
	Base metal at intermittent welds attaching longitudinal stiffeners or cover plates	E	7, 29	T or Rev
Stud welds	Shear stress on nominal shear area of stud-type shear connectors	F	14	S
Plug and slot welds	Base metal adjacent to or connected by plug or slot welds	E	30	T or Rev
	Shear stress on nominal shear area of plug or slot welds	F	30, 31	S
Mechanically fastened connections	Base metal at gross section of high-strength bolted friction-type connections, except connections subject to stress reversal and axially loaded joints that induce out-of-plane bending in connected material	B	32	T or Rev
	Base metal at net section of other mechanically fastened joints	D	33	T or Rev

Table CM-2.1.6.4.1-2
Fatigue Stress Provisions — Tension or Reversal Stresses (Cont'd)

General Condition	Situation	Joint Category	Example of a Situation [Note (1)]	Type of Stress [Note (2)]
	Base metal at net section of high-strength bolted bearing connections	B	32, 33	T or Rev

NOTES:
(1) Example numbers are from CMAA 74-2020, Figure 3.4.7-2B. See Figure CM-2.1.6.4.1-1.
(2) T = tension; Rev = reversal.

Figure CM-2.1.6.4.1-1
Joint Configuration



GENERAL NOTE: Figure 3.4.7-2B from CMAA 74-2020 is reprinted courtesy of the Crane Manufacturers Association of America.

CM-2.3.2 Component Design

CM-2.3.2.1 Girders, Beams, or Tracks. Girders may be standard rolled beams, patented shape track, or plate girders. Where necessary, auxiliary girders shall be used to support overhanging loads to minimize torsional moments on and lateral deflections of the girder. The analysis required for girders shall be in accordance with subsection CM-2.1. On spans longer than 16 ft, the ratio of span to top-flange width shall not exceed 60:1.

CM-2.3.2.2 End Trucks. The crane bridge shall be carried on end trucks designed to carry the rated load when lifted at one end of the crane bridge (closest approach). Load combinations and basic allowable stresses shall be in accordance with paras. CM-2.1.2 and CM-2.1.6.1. The wheelbase of the outermost wheels shall be one-eighth of the span or greater.

End trucks may be of the rotating-axle or fixed-axle type. Provisions shall be made to prevent a drop of the crane not more than 1 in. in the case of axle failure. When appropriate, equalizer bridge trucks shall be incorporated to promote sharing of the bridge wheel loads. Equalizer pins shall be provided between the equalizer truck and the equalizer beam or between the equalizer truck and the rigid bridge structure as appropriate to the design. A rail sweep shall be provided in front of each outside wheel and shall project below the top of the runway rail. End trucks shall also meet the requirements of the applicable paragraphs of subsection CM-2.1.

CM-2.3.3 Wind Loads

Gantry structures shall be designed to withstand wind loading conditions as specified by the owner. If loads are not specified, a load of 30 lb/ft^2 on the projected area, under nonoperating conditions, shall be used. For through-leg gantries, a check is to be made using a 5 lb/ft^2 wind load, with the lifted load at the end of the bridge.

CM-2.4 ADDITIONAL REQUIREMENTS SPECIFIC TO TRAVELING WALL CRANES

CM-2.4.1 Allowable Boom Deflections.

The maximum vertical deflection of the boom and its end tie structure produced by the boom dead load, the trolley dead load (including the hoist dead weight), and the design rated load shall not exceed $^1\!/_{600}$ of the span. When a motorized trolley is specified, the allowable vertical deflection may be increased up to $^1\!/_{225}$ of the span. Impact shall not be considered when determining deflection.

CM-2.4.2 Component Design

CM-2.4.2.1 Booms Crane booms may be fabricated with standard rolled beams and reinforced with angles, channels, or plates, as necessary. Auxiliary members may be of standard shapes, structural tube, or fabricated plates. Structural analysis shall be completed in accordance with Section CM-2.

CM-2.4.2.2 End Tie Structure

(a) End tie structure may be fabricated with standard rolled shapes, structural tube, or plate and reinforced with the same. Structural analysis shall be consistent with the requirements of Section CM-2.

(b) Loads induced from drive mechanisms, acceleration and braking, motor stall, bumper stops, and varying loads from a swinging boom, where used, shall be considered in the structural analysis.

CM-2.4.2.3 Braces and Secondary Members. Braces and secondary members may be fabricated of standard rolled beams, angles, tees, rods, structural tube, or other structural shapes. They shall be analyzed in accordance with Section CM-2.

CM-2.4.3 Design Requirements for Wall Crane Supports

(a) The manufacturer shall provide general arrangement drawings to define all reactions and special attaching considerations at all tie points to the supporting structure. The general arrangement drawings shall specify rail alignment tolerances applicable to the design.

(b) The owner shall analyze the supporting structure for all loading conditions imposed by the wall crane and any auxiliary system.

CM-2.5 ADDITIONAL REQUIREMENTS SPECIFIC TO JIB CRANES

CM-2.5.1 Allowable Deflections and Cambers

CM-2.5.1.1 Jib Boom Deflection. The maximum vertical deflection of the boom produced by the boom dead load, the trolley dead load (including the hoist dead weight), and the design-rated load shall not exceed $^1\!/_{600}$ of the span. When a motorized trolley is specified, the allowable vertical deflection may be increased up to $^1\!/_{225}$ of the span. Impact shall not be considered in determining deflection.

CM-2.5.1.2 Miscellaneous Structure Deflection. In the case of jib cranes that are self-supporting (such as freestanding or mast-type), the entire structure shall not produce a deflection greater than that given in para. CM-2.5.1.1.

CM-2.5.2 Component Design

CM-2.5.2.1 Jib Booms, Beams, or Tracks. Jib booms may be standard rolled beams and reinforced with angles, channels, or plates. Where necessary, auxiliary members shall be used to act as bracing when a full cantilever is not used.

The analysis required for jib booms shall be in accordance with Section CM-2.

CM-2.5.2.2 Columns, Posts, or Masts. Columns may be standard rolled beams, plate girders, structural tube, or structural pipe, and reinforced with angles, channels, or plates. Structural analysis shall be consistent with the requirements of subsection CM-2.1.

CM-2.5.2.3 Braces and Secondary Members. Braces and secondary members may be fabricated of standard rolled beams, angles, tees, rods and structural tube, or other structure shapes. They shall be analyzed in accordance with subsection CM-2.1.

CM-2.5.3 Jib Crane Supports

(a) All attachment point locations and load reactions to the interfacing structures and foundations shall be provided by the manufacturer.

(b) The owner shall analyze the interfacing structures and foundations for all loading conditions the jib crane may impose through its full rotational movement.

(c) Interfacing structures and foundations shall be designed such that the maximum resisting moment against overturning (based upon dead load plus rated load) will provide a safety factor of 2.

(d) For the purposes of sizing baseplates of jib cranes attached to concrete, the manufacturer shall assume a concrete ultimate compressive strength of 2,000 psi unless otherwise specified by the owner.

CM-2.6 ADDITIONAL REQUIREMENTS SPECIFIC TO MONORAIL SYSTEMS

CM-2.6.1 Allowable Deflections and Cambers

CM-2.6.1.1 Miscellaneous Structure Deflection. Deflections of components such as end ties, end trucks, and auxiliary beams shall not impair the functions for which they were designed nor cause any attachments to the crane to become dislodged or leave the crane.

CM-2.6.1.2 Monorail Beam Deflection. The maximum vertical deflection of the monorail beam produced by the beam dead load, the trolley dead load (including the hoist dead weight), and the design-rated load shall not exceed $\frac{1}{600}$ of the span between supports. Impact need not be considered in determining deflection.

CM-2.6.1.3 Monorail Camber. Where monorail beams are cambered, the recommended amount of camber is equal to the sum of the beam dead load deflection, one-half of the deflection caused by the trolley dead load (including hoist dead weight), and one-half of the deflection caused by the design-rated load. Monorail beam camber and deflection shall be considered when determining vertical clearance.

CM-2.6.2 Component Design

CM-2.6.2.1 Girders, Beams, or Tracks. Girders may be standard rolled beams, patented shape track, or plate girders. Where necessary, auxiliary girders shall be used to support overhanging loads to minimize torsional moments on and lateral deflections of the girder. The analysis required for girders shall be in accordance with Section CM-2. On spans longer than 16 ft, the ratio of span to top-flange width shall not exceed 60:1.

CM-2.6.2.2 Track Joints. Web-type or other suitable couplings shall be provided at all track joints. The maximum gap between ends of the load-carrying flange shall not exceed $\frac{1}{16}$ in.

CM-2.6.2.3 Monorail Curves. Monorail curves shall be of such radius as to permit operation of the carrier without binding.

CM-2.6.2.4 Building Expansion Joints. Where a track system crosses building expansion joints, provision shall be made to accommodate for differential expansion of the building and track.

CM-2.6.3 Inertia Forces from Drives

Inertia forces occur during acceleration or deceleration of trolley motion and depend on the driving and braking torques applied by the drive units and brakes during each cycle. These loads are longitudinal to the monorail only. This load shall be taken as 10% of the combined trolley dead load and the rated load.

CM-2.6.4 Allowable Stresses and Wheel Loads

CM-2.6.4.1 Lower Load-Carrying (Tension) Flange. The allowable stress in the lower load-carrying (tension) flange shall be 20% of the minimum ultimate strength of the material used.

CM-2.6.4.2 Compression Flange. The allowable stress in the compression flange shall be determined per Section CM-2.

CM-2.6.4.3 Allowable Wheel Loads. Allowable wheel loads shall take into account the stress imposed on the lower load-carrying flange when a carrier transfers from one track to another. Where track sections are diagonally cut at transfers, the wheel loads shall be limited by the stress imposed on the lower carrying flange.

CM-2.6.5 Monorail Supports

(a) Monorail beams shall be fastened to a supporting structure.

(b) All clamps, hanger roads, bolts, or other suspension fittings and supporting structures shall be designed to withstand the loads and forces imposed by the cranes or carriers.

(c) Where multiple hanger rods are used at a suspension point, consideration shall be given to the unequal load induced in the rods.

(d) Means shall be provided to restrain the track against damaging lateral and longitudinal movement.

(e) Where the track is suspended from hanger rod assemblies, restraining means shall be provided to prevent the hanger rod nuts from backing off the hanger rods.

(f) All monorail beam supports shall conform to the minimum design parameters as specified in Section CM-2 and the AISC Manual of Steel Construction.

Section CM-3
Mechanical Requirements, Cranes and Monorails (Type I)

CM-3.1 GENERAL

This Section covers the mechanical requirements and criteria common to all Type I cranes and monorails. Requirements for hoists and trolleys are covered under Part HT.

CM-3.1.1 Lubrication Subject to Radiation

If the crane is subjected to radiation, the lubricants shall resist the effects of gamma or neutron radiation, or provisions shall be made for changing the lubricants. If lubricants cannot be conveniently replaced, then lubricants shall be National Lubrication and Grease Institute (NLGI) Grade 0 oil containing molybdenum disulfate or NLGI Grade 1.5 grease with sodium aluminate thickener. Lubricants shall be oxidation and rust inhibited except for lubricants for wire rope.

CM-3.1.2 Design and Performance Criteria

CM-3.1.2.1 Allowable Stresses. Load-carrying parts, except structural members and gears, shall be designed such that the calculated static stress in the material, based on rated load, does not exceed 20% of the published average ultimate strength of the material. Castings, forgings, stampings, and fasteners shall be designed with allowable stress not to exceed 20% of the minimum ultimate strength of the material.

CM-3.1.2.2 Service Factors. All load combinations and factors, including stress concentrations, shall have service factors as stated for the design of specific mechanical components, as indicated in para. CM-3.1.4.

CM-3.1.2.3 Seismic Analysis

CM-3.1.2.3.1 Criteria. Analyses shall be performed to ensure retention of the load during a seismic event. In addition, analysis shall confirm that mechanical components that would damage safety-related equipment if dislodged will remain in place during a seismic event.

CM-3.1.2.3.2 Component Analysis (>33 Hz). Components whose major resonant frequency is greater than 33 Hz may be modeled as a lumped mass.

(a) 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.

(b) Loads due to vertical and horizontal motions shall act together and shall be combined in accordance with the requirements of para. CM-2.1.3.

CM-3.1.2.3.3 Component Analysis (<33 Hz). Components whose major resonant frequency is less than 33 Hz shall be analyzed dynamically. The component shall be represented by a generalized three-dimensional system of nodes. The model's geometry shall reflect the overall size, length, connectivity, and stiffness of the various structural members. An appropriate element representation of each member shall be used to describe all components that contribute significantly to stiffness.

CM-3.1.2.3.4 Allowable Stresses for Fasteners. Seismic loads shall induce stresses that, when combined with appropriate dead and live loads, do not exceed 90% of the yield strength of the fastener.

CM-3.1.3 Component Design

CM-3.1.3.1 Bridge Drives. Single failure-proof features are generally not required for bridge travel systems. However, in those cases where failure of a component could result in an owner-specified unacceptable motion for a facility, the design shall incorporate single failure-proof features to ensure that the bridge is brought to a safe stop.

Reference specific bridge (see subsections CM-3.2 through CM-3.6) for acceptable bridge drive arrangements. Where required, bridge drive motors shall be selected in accordance with Section CM-4.

CM-3.1.3.2 Brakes

CM-3.1.3.2.1 Bridge and Jib Brakes. On all powered cranes, one of the following braking means with a thermal capacity suitable for the frequency of operation shall be provided for bridge or jib.

(a) a spring-set, friction-type brake with the following characteristics:

(1) Brakes shall be provided with adjustment to compensate for wear.

(2) If holding brakes are provided, they shall have a torque rating of at least 50% of the rated motor torque and be adjustable to a minimum of 25% of the rated motor torque.

(b) a non-coasting mechanical drive that is capable of stopping the motion of the bridge within a distance in feet equal to 10% of full-load speed in feet per minute when traveling at full speed with full load

CM-3.1.3.2.2 Emergency and Parking Brakes. Emergency and parking brakes shall be provided for bridge drives and jib crane slew drives. 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.

CM-3.1.3.3 Bumpers and Stops

CM-3.1.3.3.1 Bumper Design

(a) Bridge bumpers shall be provided.
(b) Bumpers shall be designed and installed to minimize parts falling from the crane in case of breakage.
(c) For two cranes on the same runway, bumpers shall be designed and installed so that no other part of either crane will come in contact when the two cranes come together.
(d) Bumpers shall have the energy-absorbing (or energy-dissipating) capacity to stop the crane when traveling with power off in either direction at a speed of at least 40% of the rated load speed. The bumpers shall also be capable of stopping the crane (not including the lifted load) at a rate of deceleration not to exceed an average of 3 ft/sec when traveling with power off in either direction at 20% of rated load speed.

CM-3.1.3.3.2 Stop Design

(a) Runway stops shall be provided and shall be located at the limits of the bridge travel such that no part of the crane (with bumper fully compressed) will encroach upon the required clearance specified in para. GR-2.1.1.
(b) Runway stops shall be able to withstand the force applied when contacted.
(c) Runway stops that engage the tread of the wheel shall not be used for motorized cranes.

CM-3.1.3.4 Couplings. Couplings shall be selected for the torque and alignment requirements at the point of application. Solid couplings shall be steel or minimum ASTM A48 Class 40 cast iron or equal material.

CM-3.1.3.5 Mounting of Bridge Drive Components

(a) Drive components, 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.
(b) Drive components whose alignment is important to their operation shall not depend on friction, but shall use positive means, such as dowel pins, shear bars, or fitted bolts, to maintain alignment.

(c) Mechanical component connections shall be designed to accommodate all dynamic forces, such as those induced by motor start-up and braking applications.

CM-3.1.3.6 Guards

(a) Exposed moving parts, such as couplings, gears, setscrews, projecting keys, chains, chain sprockets, and reciprocating components that may constitute a hazard under normal operating conditions shall be guarded.
(b) Guards shall be securely fastened.
(c) Each guard shall be capable of supporting, without permanent deformation, a weight of 200 lb, unless the guard is located where it is not probable for a person to step on it.

CM-3.1.4 General Mechanical Components

CM-3.1.4.1 Gearing. Gearing shall be designed and manufactured in accordance with the procedures presented by the American Gear Manufacturers Association (AGMA).

When worm gearing is specified, it shall be rated with appropriate service factors. Gear lock-up shall be considered when selecting gear ratios for travel drives.

CM-3.1.4.1.1 Materials. All gears and pinions shall be constructed of steel or other material of adequate strength and durability to meet the requirements for the intended class of service and manufactured to AGMA quality class 5 or better.

CM-3.1.4.1.2 Allowable Strength and Durability Horsepower. The horsepower rating for all spur, helical, and herringbone gearing shall be based on ANSI/AGMA 2001-D04. For this Standard, the horsepower equations are as follows:

$$P_{at} = \frac{N_p d}{126,000} \times \frac{F S_{at} J}{K_v K_m P_d S_{fs} K_B} \quad \text{(CM-3-1)}$$

$$P_{ac} = \frac{N_p F I}{126,000 K_v K_m S_{fd}} \times \left(\frac{S_{ac} d C_h}{C_p} \right)^2 \quad \text{(CM-3-2)}$$

where

C_h = hardness factor (durability)
C_p = elastic coefficient
d = pitch diameter of pinion, in.
F = net face width of the narrowest of the mating gears, in.
I = geometry factor (durability)
J = geometry factor (strength)
K_B = rim thickness factor
K_m = load distribution factor
K_v = dynamic factor
N_p = pinion speed, rpm

P_{ac} = allowable durability, hp
P_{at} = allowable strength, hp
P_d = transverse diametral pitch, 1/in.
S_{ac} = allowable contact stress number for material, psi
S_{at} = allowable bending stress for material, psi (strength)
S_{fd} = crane service factor (durability)
S_{fs} = crane service factor (strength)

The values for C_p, I, J, K_B, K_m, K_v, S_{ac}, and S_{at} can be determined from the tables and curves in ANSI/AGMA 2001-D-04, and S_{fs} from Table CM-3.1.4.1.2-1. The remaining values will be physical characteristics pertaining to the gears for their operation characteristics.

Crane service factor, S_{fd}, shall be determined from the formula $S_{fd} = C_d \times K_w$. For specific K_w values, see eq. (CM-3-3). For C_d, the machinery service factor, see Table CM-3.1.4.1.2-2.

$$K_w = \frac{2(\text{maximum load}) + \text{minimum load}}{3(\text{maximum load})} \quad \text{(CM-3-3)}$$

CM-3.1.4.1.3 Lubrication. Means shall be provided to ensure adequate and proper lubrication for all gearing. All gearing, except the final reduction at the wheels, shall run in oil or be splash lubricated. Selection of lubricants shall be based on the guidelines found in ANSI/AGMA 9005 or as recommended by the gear manufacturer.

CM-3.1.4.2 Antifriction Bearings

(a) Antifriction bearings shall be selected to give a minimum life expectancy based on full rated speed as shown in Table CM-3.1.4.2-1.

(b) Use K_w load factor for all applications.

(c) Due consideration shall be given to the selection of the bearing if a crane is used for a limited time at an increased service class, such as during a construction phase.

CM-3.1.4.2.1 Sleeve Bearings. Bronze sleeve bearings shall have a maximum allowable unit bearing pressure of 1,000 psi on the projected area.

CM-3.1.4.2.2 Lubrication. All bearings shall be provided with proper lubrication or means of lubrication. Bearing enclosures shall be designed to exclude dirt and prevent leakage of oil or grease.

CM-3.1.4.3 Bridge Drive Shafts

CM-3.1.4.3.1 General. Drive shafting shall be designed for the maximum wheel load in combination with the maximum torque load.

CM-3.1.4.3.2 Material. Shafts shall be cold-rolled or processed to have equivalent material properties. Bridge cross-shaft sections that do not carry gears may be of material other than that described in CM-3.1.4.3.2.

Table CM-3.1.4.1.2-1
Crane Class Factors for Strength Horsepower Rating, S_{fs}

Service Class	S_{fs} [Note (1)]
A	0.75
B	0.85
C	0.90
D	0.95

NOTE: (1) Crane class factors for strength horsepower rating, S_{fs}, are from CMAA 74-2020.

Table CM-3.1.4.1.2-2
Machinery Service Factor, C_d

Service Class	C_d [Note (1)]
A	0.64
B	0.72
C	0.80
D	0.90

NOTE: (1) Values for machinery service factor, C_d, are from CMAA 74-2020.

Table CM-3.1.4.2-1
ABMA L10 Bearing Life

Service Class	L10 Bearing Life, hr [Note (1)]
A	1,250
B	2,500
C	5,000
D	10,000

NOTE: (1) Values for American Bearing Manufacturers Association (ABMA) L10 bearing life are from CMAA 74-2020.

CM-3.1.4.3.3 Bearing Spacing for Rotating Shafts. The bearing spacing for shafts rotating at less than 400 rpm shall not exceed that calculated per eq. (CM-3-4):

$$L = \sqrt[3]{432{,}000D^2} \qquad \text{(CM-3-4)}$$

where

D = shaft diameter, in.
L = distance between bearing centers, in.

When the shaft speed exceeds 400 rpm, the bearing spacing shall not exceed that determined by eq. (CM-3-5) or eq. (CM-3-4), whichever is less, to avoid objectionable vibration at critical shaft speeds.

$$L = \sqrt{\frac{4{,}760{,}000D}{1.2N}} \qquad \text{(CM-3-5)}$$

where

N = maximum shaft speed, rpm

CM-3.1.4.3.4 Torsional Deflection of the Bridge. The torsional deflection of the bridge cross shaft shall not exceed 0.10 deg/ft for the following drives and loads:

(a) an A-1 drive when 67% full-load, bridge drive-rated motor torque is applied
(b) an A-2 drive when 50% full-load, bridge drive rated-motor torque is applied
(c) an A-4 drive when 100% full-load, bridge drive rated-motor torque is applied

Bridge drive-rated motor torque shall be increased by any gear reduction between the motor and the shaft. In addition, the applied torque shall result in a bridge drive wheel movement no greater than 1% of the wheel circumference or ½ in., whichever is less.

CM-3.1.4.3.5 Stress Calculations. All shafting shall be designed to meet the stresses encountered in actual operation, including the effects of brake torque. When significant stresses are produced by other forces, these forces shall be positioned to provide the maximum stresses at the section under consideration. Impact shall not be included.

(a) Static Stress Check for Operating Conditions

(1) For shafting subjected to axial loads and not limited by buckling, the stress, σ, shall be calculated as follows:

$$\sigma = \frac{P}{A} \qquad \text{(CM-3-6)}$$

where

A = cross-sectional area of shaft, in.^{2}
P = total axial load, lb

This axial stress shall not exceed $S_u/5$.

(2) For shafting loaded in bending, the stress shall be calculated as follows:

$$\sigma = \frac{Mr}{I} \qquad \text{(CM-3-7)}$$

where

I = bending moment of inertia at point of examination, ft-lb-sec^2
M = bending moment at point of examination, in.-lb.
r = outside radius of shaft at point of examination, in.

This bending stress shall not exceed $S_u/5$.

(3) For shafting loaded in torque, the shear stress, τ, shall be calculated as follows:

$$\tau = \frac{Tr}{J} \qquad \text{(CM-3-8)}$$

where

J = polar moment of inertia of shaft at point of examination, in.^{4}
T = torque at point of examination, in.-lb.

This shear stress shall not exceed $S_u/(5\sqrt{3})$.

(4) Transverse shear stress in shafting shall be calculated as follows:

(-a) For solid shaft

$$\tau = \frac{1.33V}{A} \qquad \text{(CM-3-9)}$$

where

A = cross-sectional area at point of examination, in.^{2}
V = shear load at point of examination, lb

(-b) For hollow shafts

$$\tau = \frac{2V}{A} \qquad \text{(CM-3-10)}$$

These shear stresses shall not exceed $S_u/(5\sqrt{3})$.

(5) When combinations of stresses are present on the same element, they shall be combined as follows:

(-a) For axial and bending stresses

$$\sigma = \sigma_1 + \sigma_2 + \sigma_3 \ldots + \sigma_n$$

and shall not exceed $S_u/5$.

(-b) For shear stresses

$$\tau = \tau_1 + \tau_2 + \tau_3 \ldots + \tau_n$$

and shall not exceed $S_u/(5\sqrt{3})$.

(-c) For axial and bending with shear

$$\sigma_t = \sqrt{\sigma^2 + 3\tau^2} \qquad \text{(CM-3-11)}$$

and shall not exceed $S_u/5$.

Note that bending and torsional stresses are maximum on the outer fibers of the shaft and must be combined. The transverse shear stresses are maximum at the center of the shaft and do not combine with bending or torsional stresses.

(b) Fatigue Stress Check for Fluctuating Operating Stresses. Any shafting subjected to fluctuating stresses, such as bending in rotating shafts or the torsion in reversing drives, shall be checked for fatigue. This check shall be performed at points of geometric discontinuity where stress concentrations exist, such as fillets, holts, keys, and press fits. Pure stresses shall be calculated using appropriate stress multiplication factors. The allowable stresses are as follows:

(1) Tensile and bending stress

$$\sigma K_t \le \frac{S_e}{K_c} \qquad \text{(CM-3-12)}$$

(2) Shear and combined shear stress

$$\tau K_s \le \frac{S_e}{K_c\sqrt{3}} \qquad \text{(CM-3-13)}$$

(3) For combined stresses, where all of the shear and bending stresses are fluctuating

$$\sigma_t = \sqrt{(K_t\sigma)^2 + 3(K_s\tau)^2} \le \frac{S_e}{K_c} \qquad \text{(CM-3-14)}$$

(4) For combined shear and bending stresses, where only part of the stresses are fluctuating

$$\sigma_t = \sqrt{\left(\sigma_{av} + \frac{K_t S_{yp}\sigma_r}{S_e}\right)^2 + 3\left(\tau_{av} + \frac{K_s S_{yp}\tau_r}{S_e}\right)^2} \le \frac{S_{yp}}{K_c} \qquad \text{(CM-3-15)}$$

where

K_c = crane class factor (see Table CM-3.1.4.3.5-1)
K_s = stress amplification factor
K_{sc} = surface condition factor (see Table CM-3.1.4.3.5-2)
K_t = stress amplification factor for tension or bending
S_e = endurance strength of shaft material, psi = $0.36S_u{}'K_{sc}$
S_u = average ultimate tensile strength of shaft material, psi
$S_u{}'$ = minimum ultimate tensile strength of shaft material, psi
S_{yp} = minimum yield strength of shaft material, psi
σ_{av} = that part of the bending stress not due to fluctuating loads, psi
σ_r = that part of the bending stress due to fluctuating loads, psi
τ_{av} = that part of the shear stress not due to fluctuating loads, psi
τ_r = that part of the shear stress due to fluctuating loads, psi

(c) Bearing Stress in Shafts. Shafting in bearings shall be checked for operating conditions. The bearing stress is calculated by dividing the radial load, P, by the projected area:

$$P/(dL)$$

where

d = shaft diameter, in.
L = bearing length, in.

This bearing stress shall not exceed 50% of the minimum yield for non-rotating shafting.

This bearing stress shall not exceed 20% of the minimum yield for oscillating shafting when not limited by the bushing material.

CM-3.1.4.4 Wheel Assembly

CM-3.1.4.4.1 Top-Running Bridge Wheel Design

(a) Unless other means of restricting lateral movement are provided (such as side rollers), wheels shall be double flanged with treads accurately machined. Bridge wheels may have either straight treads or tapered treads assembled with the large diameter toward the center of the span. Drive wheels shall be machined in pairs within 0.001 in./in. of diameter with a maximum of 0.010 in. on the diameter, whichever case is smaller.

Table CM-3.1.4.3.5-1
Crane Class Factor, K_c

Service Class	K_c [Note (1)]
A	1.000
B	1.015
C	1.030
D	1.060

NOTE: (1) The crane class factor, K_c, is from CMAA 74-2020.

Table CM-3.1.4.3.5-2
Surface Condition Factor, K_{sc}

K_{sc} [Note (1)]	Shafting Type
1.40	For polished, heat-treated, and inspected shafting
1.00	For machined, heat-treated, and inspected shafting
0.75	For machined, general-use shafting

NOTE: (1) The surface condition factor, K_{sc}, is from CMAA 74-2020.

(b) Wheels shall be designed to carry the maximum wheel load under normal conditions without undue wear. The maximum wheel load is the wheel load produced with the trolley handling the rated load in the position to produce the maximum reaction at the wheel, not including impact. When sizing wheels and rails, the following parameters shall be considered:

D = wheel diameter, in.
K = hardness coefficient of the wheel
= BHN × 5 (for wheels with BHN <260)
= $1{,}300(\text{BHN}/260)^{0.33}$ (for wheels with BHN >260)
W = effective rail head width, in.

The bridge and trolley durability wheel loadings for different wheel hardness values and sizes in combination with different rail sizes are shown in Table CM-3.1.4.4.1-1. The values in the table are established by the product of KDW.

(c) To use Table CM-3.1.4.4.1-1, first determine the equivalent durability wheel load, P_e:

$$P_e = \text{maximum wheel load} \times K_{\text{wl}}$$

where

K_{wl} = wheel load service coefficient [see (g)]
= $K_{\text{bw}} C_s S_m$ [see (d) through (f)]

(d) Load factor, K_{bw}, can be determined as follows:

$$K_{\text{bw}} = \frac{0.75(\text{BW}) + f(\text{LL}) + 0.5(\text{TW}) - 0.5f(\text{TW})}{0.75(\text{BW}) + 1.5f(\text{LL})} \quad \text{(CM-3-16)}$$

where

BW = bridge weight, lb
f = X/span (see Figure CM-3.1.4.4.1-1)
LL = trolley weight + rated load, lb
TW = trolley weight, lb

See Table CM-3.1.4.4.1-2.

(e) The speed factor, C_s, depends on the rotational speed of the wheel and is listed in Table CM-3.1.4.4.1-3. These factors are obtained from eqs. (CM-3-17) and (CM-3-18).

(1) For rpm ≤31.5

$$C_s = \left[1 + \left(\frac{rpm - 31.5}{360}\right)\right]^2 \quad \text{(CM-3-17)}$$

(2) For rpm >31.5

$$C_s = 1 + \left(\frac{rpm - 31.5}{328.5}\right) \quad \text{(CM-3-18)}$$

(f) The wheel service factor, S_m, is equal to 1.25 times the machinery service factor, C_d, and is shown in Table CM-3.1.4.4.1-4. The wheel service factor is greater than the machinery service factor because the interaction between rail and wheel is more demanding in terms of durability than the interaction between well-aligned and lubricated machined parts.

(g) The wheel load service coefficient, K_{wl}, may not be smaller than the K_{wl} minimum shown in Table CM-3.1.4.4.1-4.

(h) The equivalent durability wheel load, P_e, shall not exceed the maximum permissible wheel load, P, in Table CM-3.1.4.4.1-1.

(i) Straight-tread wheels should be approximately ¾ in. to 1 in. wider than the rail head. Tapered-tread wheels may be 150% wider than straight-tread wheels or as recommended by the crane manufacturer.

(j) When rotating axles are used, wheels shall be mounted on the axle with press fit alone, press fit and keys, or keys alone.

CM-3.1.4.4.2 Under-Running Bridge Wheel Design

(a) All under-running bridge truck wheels shall be designed to suit the surface on which they run. Drive wheels shall be the same diameter within a tolerance of 0.010 in.

(b) When flangeless wheels are used, they shall be provided with a side roller arrangement.

(c) Wheels shall be designed to carry the maximum wheel load under normal conditions. The wheel load shown in Table CM-3.1.4.4.2-1 is that load produced with the trolley handling the rated load in a position to exert the maximum load, not including impact.

NOTE: A reduction in the allowable wheel load may be necessary to satisfy the runway lower flange stress requirements.

CM-3.1.4.4.3 Material. Wheels shall be cast iron or rolled, forged, or cast steel with a minimum hardness of 200 BHN. For special applications, other materials may be used with permission from the owner and with consideration of hardness, impact strength, and brittleness.

CM-3.1.4.4.4 Bearings. Wheel bearings shall be single or double row, combination radial and thrust, anti-friction precision type. Bearings shall be prelubricated and sealed or provided with fittings and seals for pressure lubrication.

CM-3.1.4.4.5 Safety Lugs. All wheel sets shall have drop plates limiting the movement of the immediate structure to 1 in. in the event of axle or bearing failure.

CM-3.1.5 Miscellaneous

CM-3.1.5.1 Hand-Chain Wheels

(a) Hand-chain wheels shall have pockets formed to allow proper engagement of the hand chain.

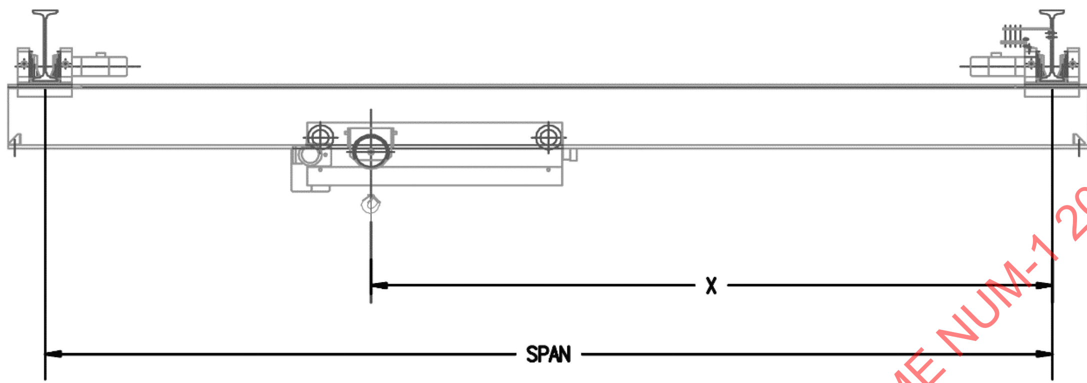
Table CM-3.1.4.4.1-1
Maximum Permissible Bridge Wheel Loading

Wheel BHN	Wheel Diameter, *D*, in.	Bridge Wheel Loading, lb, by Rail Type: ASCE 20 lb	ASCE 25 lb	ASCE 30 lb	ASCE 40 lb	ARA-A 90 lb	ASCE 60 lb, ASCE 70 lb, and ARA-B 100 lb	ASCE 80 lb, ASCE 85 lb, ARA-A 100 lb F, BETH 104 lb, USS 105 lb	ASCE 100 lb	BETH and USS 135 lb
200	5	4,200	5,000	5,300	...	...	...	...	...	...
	6	5,050	6,000	6,400	7,500	...	...	...	...	...
	8	6,750	8,000	8,500	10,000	...	...	...	...	...
	9	7,600	9,000	9,550	11,250	14,900	15,750	...	...	...
	10	8,450	10,000	10,650	12,500	16,550	17,500	...	...	...
	12	...	12,000	12,750	15,000	19,850	21,000	22,500	25,500	...
	15	...	...	15,950	18,750	24,850	26,250	28,150	31,850	...
	18	...	...	19,150	22,500	29,800	31,500	33,750	38,250	40,500
260	5	5,500	6,500	6,900	...	...	...	...	...	...
	6	6,600	7,800	8,300	9,750	...	...	...	...	...
	8	8,800	10,400	11,050	13,000	...	...	...	...	...
	9	9,850	11,700	12,450	14,600	19,400	20,450	...	...	...
	10	10,950	13,000	13,800	16,250	21,550	22,750	...	...	...
	12	...	15,600	16,600	19,500	25,850	27,300	29,250	33,150	...
	15	...	...	20,750	24,400	32,300	34,100	36,550	41,450	...
	18	...	...	24,850	29,250	38,750	40,950	43,850	48,700	52,650
320	5	5,850	6,950	7,400	...	...	...	...	...	...
	6	7,050	8,350	8,900	10,450	...	...	...	...	...
	8	9,400	11,150	11,850	13,900	...	...	...	...	...
	9	10,550	12,550	13,300	15,650	20,750	21,950	...	...	...
	10	11,750	13,900	14,800	17,400	23,050	24,350	...	...	...
	12	...	16,700	17,750	20,900	27,650	29,250	31,300	35,500	...
	15	...	...	22,200	26,100	34,600	36,550	39,150	44,400	...
	18	...	...	26,650	31,300	41,500	43,850	47,000	53,250	86,400
58 RC (615 BHN)	5	7,300	8,650	9,200	...	...	...	...	...	...
	6	8,750	10,350	11,000	12,950	...	...	...	...	...
	8	11,650	13,800	14,700	17,250	...	...	...	...	...
	9	13,200	15,550	16,500	19,450	25,750	27,200	...	...	...
	10	14,600	17,250	18,350	21,600	28,600	30,200	...	...	...
	12	...	20,700	22,050	25,900	34,300	36,250	38,850	44,050	...
	15	...	...	27,550	32,400	42,900	45,350	48,550	55,050	...
	18	...	...	33,050	38,850	51,500	54,400	58,300	66,050	69,950
Effective Width of Rail Head, *W* (Top of Head Minus Corner), in.		0.844	1.000	1.083	1.250	1.654	1.750	1.875	2.125	2.250

Legend:
ASCE = American Society of Civil Engineers
ARA = American Railway Association
BETH = Bethlehem Steel
USS = U.S. Steel

GENERAL NOTE: Bridge wheel loadings, lb, are from CMAA 74-2020.

Figure CM-3.1.4.4.1-1 Bridge Span



GENERAL NOTE: The figure, from para. 4.7.1.3 of CMAA 74-2020, is reprinted courtesy of the Crane Manufacturers Association of America.

Table CM-3.1.4.4.1-2 Bridge Load Factor, K_{bw}

Bridge Span, ft	Bridge Load Factor, K_{bw}, for Capacity of [Note (1)]							
	3 ton	5 ton	7.5 ton	10 ton	15 ton	20 ton	25 ton	30 ton
20	0.812	0.782	0.762	0.747	0.732	0.722	0.716	0.716
30	0.817	0.785	0.767	0.750	0.736	0.725	0.718	0.718
40	0.827	0.794	0.777	0.760	0.744	0.732	0.723	0.723
50	0.842	0.809	0.791	0.771	0.758	0.740	0.738	0.731
60	0.861	0.830	0.807	0.790	0.773	0.754	0.747	0.741
70	0.877	0.844	0.825	0.807	0.789	0.768	0.760	0.752
80	0.888	0.857	0.835	0.818	0.802	0.779	0.770	0.761

GENERAL NOTE: K_{bw} is based on the worst-case scenario with trolley against stop.

NOTE: (1) Bridge load factors, K_{bw}, are from CMAA 74-2020.

Table CM-3.1.4.4.1-3 Speed Factor, C_s

Wheel Diameter, in.	Speed Factor, C_s, for Speed of [Note (1)]								
	30 ft/min	50 ft/min	75 ft/min	100 ft/min	125 ft/min	150 ft/min	175 ft/min	200 ft/min	250 ft/min
5	0.952	1.020	1.078	1.136	1.194	1.252	1.310	1.368	1.485
6	0.932	1.001	1.049	1.098	1.146	1.194	1.243	1.291	1.388
8	0.907	0.958	1.013	1.049	1.086	1.122	1.158	1.195	1.267
9	0.898	0.944	1.001	1.033	1.066	1.098	1.130	1.163	1.227
10	0.892	0.932	0.984	1.020	1.049	1.079	1.108	1.137	1.195
12	0.882	0.915	0.958	1.001	1.025	1.049	1.074	1.098	1.146
15	0.872	0.898	0.932	0.967	1.001	1.020	1.040	1.059	1.098
18	0.865	0.887	0.915	0.944	0.973	1.001	1.017	1.033	1.066

NOTE: (1) Speed factors, C_s, are from CMAA 74-2020.

Table CM-3.1.4.4.1-4 Wheel Service Factor, S_m, and Minimum Service Factor, K_{wl}

Service Class	S_m	Minimum K_{wl}
A	0.80	0.75
B	0.90	0.75
C	1.00	0.80
D	1.12	0.85

GENERAL NOTE: Wheel service factors, S_{wl}, and minimum load service factors, K_{wl}, are from CMAA 74-2020.

Table CM-3.1.4.4.2-1 Maximum Wheel Loads for I Beams and Wide-Flange Beams

Wheel Diameter, D, in.	Contour Tread, in. [Notes (1), (2)]				Convex Tread, in. [Note (3)]			
	$W = ^1/_2$	$W = 1$	$W = 1^1/_2$	$W = 2$	$W = ^1/_2$	$W = 1$	$W = 1^1/_2$	$W = 2$
4	2,000	4,000	6,000	8,000	1,200	2,400	3,600	4,800
5	2,500	5,000	7,500	10,000	1,500	3,000	4,500	6,000
6	3,000	6,000	9,000	12,000	1,800	3,600	5,400	7,200
7	3,500	7,000	10,500	14,000	2,100	4,200	6,300	8,400
8	4,000	8,000	12,000	16,000	2,400	4,800	7,200	9,600
9	4,500	9,000	13,500	18,000	2,700	5,400	8,100	10,800
10	5,000	10,000	15,000	20,000	3,000	6,000	9,000	12,000

GENERAL NOTES:
(a) Maximum wheel loads for I beams and wide-flange beams are from CMAA 74-2020.
(b) W = width of wheel tread exclusive of flange, in.
(c) Charted values are based on wheels with BHN of 200. Larger wheel loads are obtainable with suitable material and with higher BHN.

NOTES:
(1) Values provided are for contour tread where the wheel tread matches the rolling surface of the lower flange of the track beam.
(2) For contour tread, P (wheel load) = 1,000WD, lb.
(3) For convex tread, P (wheel load) = 600WD, lb.

(b) The wheels shall be equipped with a chain guide that will permit operation of the hand chain from an angle 10 deg out from either side of the chain wheel without slipping or jumping the wheel rim.

(c) All hand chains shall be guided to guard against disengagement from the hand-chain wheel.

CM-3.1.5.2 Hand Chains

(a) Hand chains shall be of the link-chain type. Each link shall be of uniform size and shape and have an accurate pitch to reliably pass over and around the hand-chain wheels.

(b) Hand chains shall be endless-link chains and shall have a drop that is approximately 2 ft above the operator's floor level.

(c) Hand chains on booms without motorized rotation shall withstand, without permanent distortion, a force of three times the pull required to rotate the boom with a capacity load on the boom.

CM-3.2 ADDITIONAL DESIGN REQUIREMENTS SPECIFIC TO UNDERHUNG CRANES

CM-3.2.1 Bridge Drive

The bridge drive arrangements normally used with underhung bridge cranes are illustrated in Figures CM-3.2.1-1 and CM-3.2.1-2. An underhung bridge has a minimum of four pairs of wheels and shall use a drive arrangement where at least one pair of wheels is driven on each end truck. Underhung bridges running on multiple runways may be driven by wheel pairs on two or more end trucks. End trucks may be driven by more than one wheel pair.

CM-3.2.1.1 Bridge Drive Arrangements

(a) A-2 Drive

(1) The motor is connected to a self-contained gear reducer unit located near the center of the bridge. The gear reducer is connected to a set of squaring shafts that in turn are connected to the end truck drive pinions. The pinions drive the geared section of the wheels.

(2) The motor is connected by chain and sprockets or through a self-contained reducer to a squaring shaft that in turn is connected to the axle of the rubber wheels at each bridge end truck. The rubber drive wheels are arranged to provide spring-loaded contact to the underside of the runway rail for traction drive.

(b) A-4 Drive

(1) A mechanically independent drive is provided at each bridge end truck. The drive motor is directly connected to the integral self-contained gear reduction unit that in turn is connected to the drive pinion that drives the geared section of the bridge wheels.

(2) A mechanically independent drive is provided at each bridge end truck. The drive motor is directly connected to the integral self-contained gear reduction unit that in turn is connected to the axle of the rubber wheel. The rubber drive wheel is arranged to provide spring-loaded contact to the underside of the runway rail for traction drive.

CM-3.2.2 Bridge Interlocking Mechanisms

(a) Interlock mechanisms for underhung cranes shall maintain alignment between mating track sections and shall provide smooth trolley transfer across sections.

(b) Stops or forks shall be part of the interlock mechanisms to prevent the trolley from rolling off open track ends. When girders and spur tracks or transfer sections are aligned and interlock mechanisms are engaged, stops or forks shall be in the open position and permit transfer of the trolley. When girders and spurs or transfer tracks are not aligned and the interlock mechanisms are not engaged, stops or forks shall be in the closed position.

(c) Interlock mechanisms shall be designed to limit vertical misalignment to less than $\frac{1}{8}$ in.

(d) Interlocking cranes and mating tracks shall have a gap of less than $\frac{1}{4}$ in. between adjacent ends of the load-carrying flange.

CM-3.3 ADDITIONAL REQUIREMENTS SPECIFIC TO TOP-RUNNING BRIDGE AND GANTRY CRANES

CM-3.3.1 Bridge Drives for Top-Running Cranes

A top-running bridge has a minimum of four wheels and shall use a drive arrangement where at least one wheel is driven on each end truck.

CM-3.3.1.1 Bridge Drive Arrangements. Bridge drive arrangements normally used with top-running bridge cranes are illustrated in Figures CM-3.3.1.1-1 through CM-3.3.1.1-3.

(a) A-1 Drive (Figure CM-3.3.1.1-1). The motor is located near the center of the bridge span and is connected to a self-contained gear reduction unit, also located near the span center, that in turn is connected to a set of line shafts that are connected to the wheel axles.

(b) A-2 Drive (Figure CM-3.3.1.1-2). The motor is located near the center of the bridge span and connected by a flexible coupling to a self-contained gear reduction unit, also located near the span center, that in turn is connected to a set of line shafts by solid or semiflexible couplings. Each line shaft is connected to a pinion at the end truck that meshes with the drive gear. Connecting couplings between the line shaft and pinion are semiflexible. All other couplings, if required, are of the solid type.

(c) A-4 Drive (Figure CM-3.3.1.1-3). Two mechanically independent drive arrangements are provided, one unit at each end truck of the bridge. Motors are connected to the gear reduction units that in turn are connected to the wheel axles.

Figure CM-3.2.1-1
Arrangement of Crane Bridge Drives (A-2 Drive)

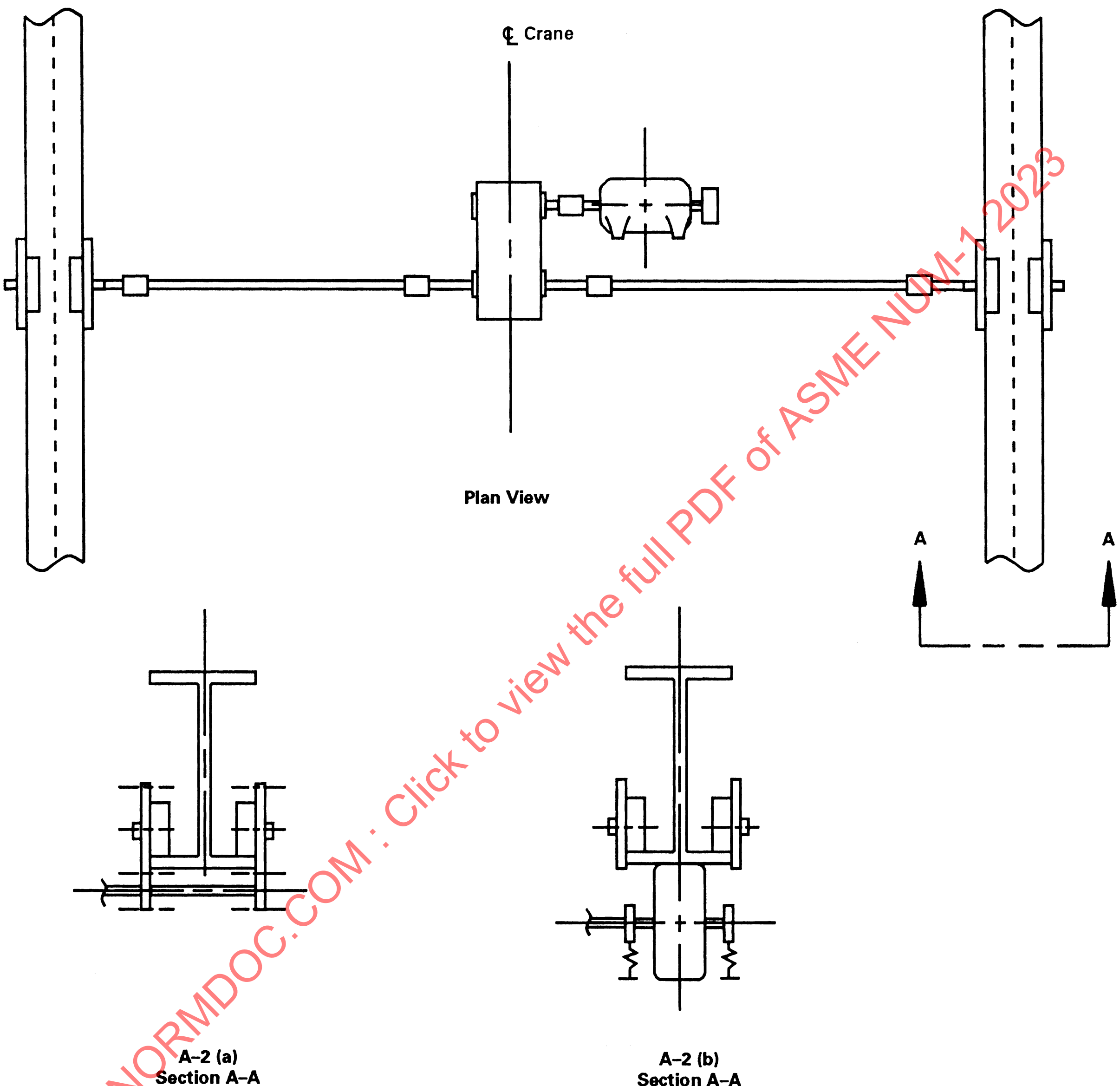


Figure CM-3.2.1-2
Arrangement of Crane Bridge Drives (A-4 Drive)

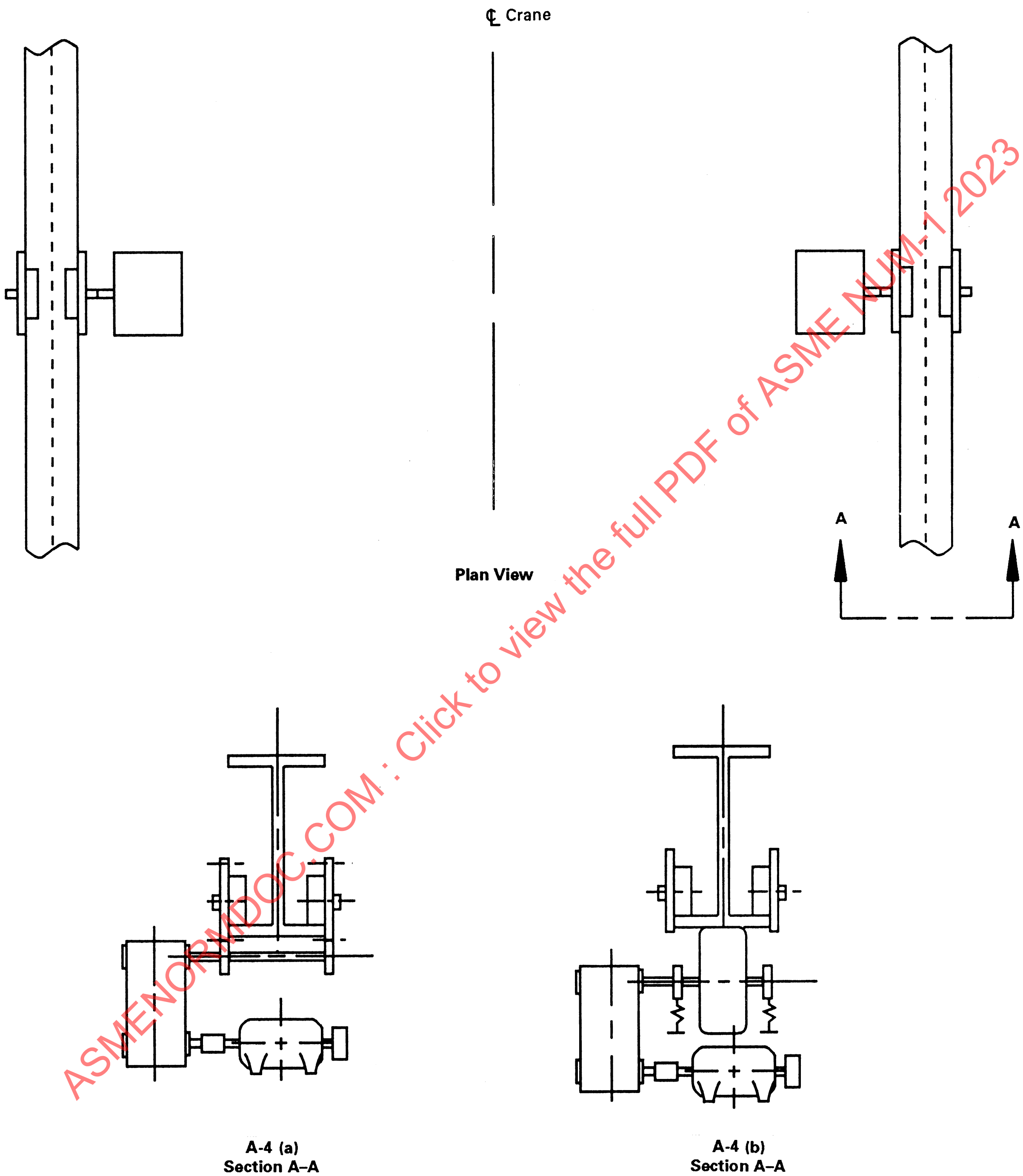


Figure CM-3.3.1.1-1
Arrangement of Crane Bridge Drives (A-1 Drive)

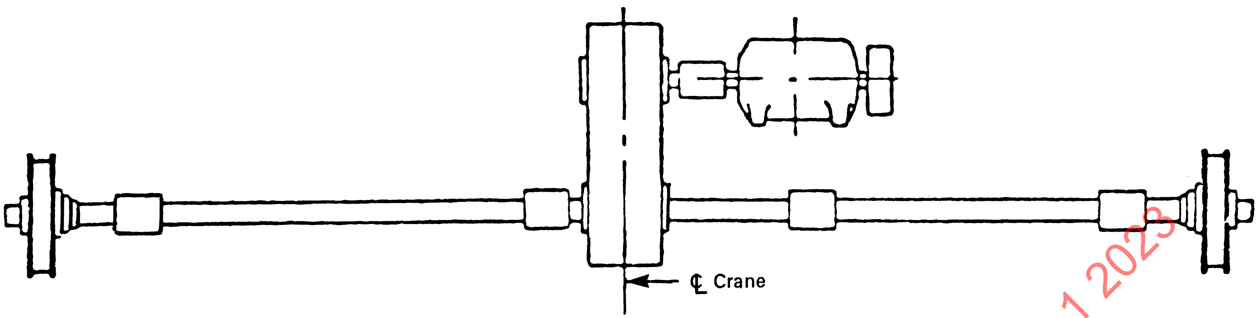


Figure CM-3.3.1.1-2
Arrangement of Crane Bridge Drives (A-2 Drive)

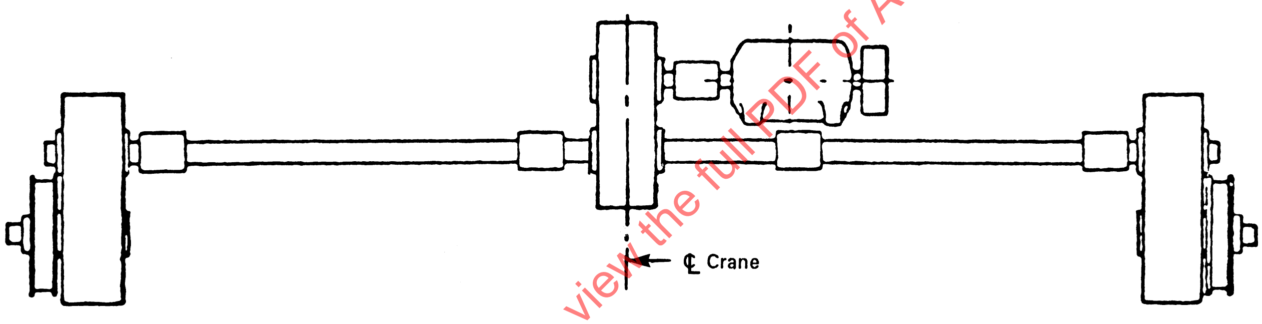
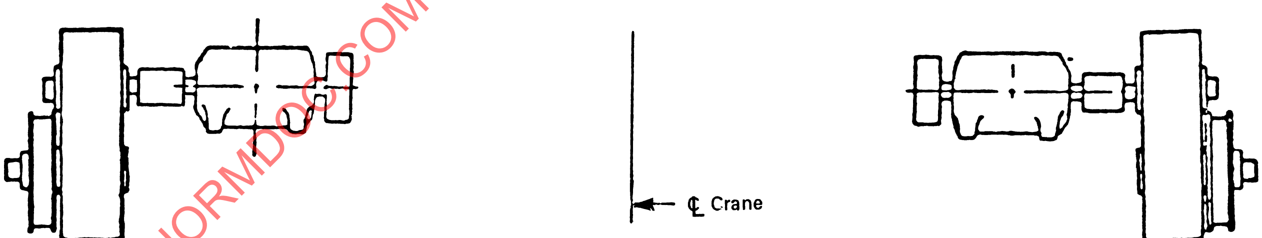


Figure CM-3.3.1.1-3
Arrangement of Crane Bridge Drives (A-4 Drive)



CM-3.3.2 Bridge Drives for Gantry Cranes

For bridge drives on gantry cranes, the number of driven wheels shall be selected based on crane acceleration rates to prevent wheel skidding.

CM-3.3.3 Gantry Crane Drive Brakes

Each motorized drive on gantry cranes shall be provided with a suitable brake that is sized as described in Section CM-3.

CM-3.4 ADDITIONAL DESIGN REQUIREMENTS SPECIFIC TO TRAVELING WALL CRANES

CM-3.4.1 Wall Crane End Truck Configuration

The wall crane shall have vertical and horizontal end trucks and a cantilevered girder. The driven vertical truck may be top running with wheels on standard rails or underhung from the lower flange of an I-beam or patented track. The horizontal-reaction idler trucks may be constructed similar to the vertical truck, either top running or under running (see Figure GR-6.2.3-1).

CM-3.4.2 End Truck Assembly

For the truck assembly drive, if the vertical wheels are top running, a minimum of two wheels shall be driven. If the vertical wheels are under running, a minimum of two pairs of wheels shall be driven.

CM-3.4.3 Wall Crane Drive Brakes

Each motorized drive shall be provided with a suitable brake, sized as described in Section CM-3.

CM-3.5 ADDITIONAL REQUIREMENTS SPECIFIC TO JIB CRANES

CM-3.5.1 Considerations for the Boom

(a) If the jib crane is subject to damage due to wind loading, a means shall be provided to tie down or restrain the boom during storage.

(b) If the jib crane's boom is located 16 ft or more above the operating floor, or if the jib crane is subject to wind loading, the jib boom's rotation should be hand-gear powered or motorized.

(c) If a jib rotation allows the boom to move into an area of facility-unacceptable excursion, positive means to tie down or restrain the boom for storage shall be provided.

CM-3.5.2 Wall-Bracket-Type Jib Cranes

Rotational stops for the jib boom shall be specified by the owner, if required.

CM-3.5.3 Freestanding or Mast-Type Jib Cranes

Jib boom rotation shall be limited unless the power service connection provides for continuous rotation.

CM-3.6 ADDITIONAL REQUIREMENTS SPECIFIC TO MONORAIL SYSTEMS

CM-3.6.1 Track

CM-3.6.1.1 Track Switches

CM-3.6.1.1.1 Track Switch Types. Track switches shall be of the tongue, rotary, cross-track, or sliding type. Track switches shall maintain alignment of the incoming tracks and switch tracks with a maximum gap of $^{3}\!/_{16}$ in. between adjacent ends of the load-carrying flanges. Switches may be operated by pull chains or ropes; manually; or by electric, pneumatic, or hydraulicly operated devices.

CM-3.6.1.1.2 Track Switch Stops. Stops shall be provided as an integral part of the switch to protect the end of an incoming track when the switch track is not aligned with the incoming track. Stops shall resist the impact forces of a fully loaded carrier traveling at a speed of 150 ft/min or 50% of the full-load speed if the carrier is motor propelled. Guards shall also be provided to prevent a carrier on the movable track from running off the movable track when it is not engaged with an incoming track.

CM-3.6.1.1.3 Track Switch Holding. Means shall be provided to hold the movable frame in alignment during the passage of carriers through the track switch.

CM-3.6.1.2 Track Openers. Track openers, when required, shall be specified by the owner. The gap between the adjacent track and the track opener shall be not more than $^{3}\!/_{16}$ in. Forks or stops shall be provided to prevent a carrier from running off either of the open ends of the track when the movable section is not in alignment with the track.

CM-3.6.1.3 Vertical Drop or Lift Sections. Type I vertical drop or lift sections shall have structural, mechanical, and electrical components meeting the Type I requirements. The drop or lift section hoist shall be either a Type IA or Type IB hoist.

CM-3.6.1.3.1 Alignment

(a) Vertical drop or lift sections shall maintain alignment of the stationary tracks and movable tracks with a maximum gap of $^{3}\!/_{16}$ in. between adjacent ends of the load-carrying flanges.

(b) When sections are operated by electric, pneumatic, or hydraulic power, means shall be provided to limit the vertical travel for alignment of the movable track with the stationary tracks. Vertical misalignment between the

movable track and stationary tracks shall not exceed $^1\!/_{16}$ in.

CM-3.6.1.3.2 Stops. Stops shall be an integral part of the movable and stationary track and shall prevent a carrier from running off the open ends of the movable or stationary track when the movable track is not in alignment with the stationary tracks.

Section CM-4
Electrical Requirements, Cranes and Monorails (Type I)

CM-4.1 GENERAL

This Section covers the electrical requirements and criteria common to all Type I cranes and monorails. Requirements for hoists and trolleys are covered under Part HT.

CM-4.1.1 Electrical Components

CM-4.1.1.1 Crane Controls. The type of control supplied for a traverse drive shall result in operation complying with the specified performance as defined in Section GR-3.

CM-4.1.1.1.1 Types of Control

(a) Common Control Systems. Common control systems may be one of the following:

(1) single-speed alternating current (AC) magnetic reversing, which uses an AC squirrel-cage induction motor (also see para. CM-4.1.1.1.2).

(2) two-speed AC magnetic reversing, which uses a dual-wound AC squirrel-cage induction motor. Speed ratios under any load are normally 3:1, but may also be furnished in other ratios, such as 2:1 or 4:1 (see also para. CM-4.1.1.1.2).

(3) variable-speed AC magnetic reversing, which is a type of constant-potential AC control that uses resistance in the secondary of an AC-wound rotor induction motor. Three to five speed steps are normally provided, with the speed at each step varying depending on the load.

(4) AC variable-frequency control, which uses an AC squirrel-cage induction motor and provides either stepped or stepless speed control by varying the motor frequency (see para. CM-4.1.1.1.6).

(b) Other Control Systems. Other control systems, such as adjustable-voltage direct current (DC) and adjustable voltage AC, may be required depending on the specific application or owner specifications.

CM-4.1.1.1.2 Cushioned Start Devices

(a) Cushioned start devices are used with single-speed and two-speed AC magnetic-reversing controls to control the rate of acceleration by limiting the starting voltage of the AC squirrel-cage induction motor.

(b) A cushioned start device should be used on single-speed and two-speed applications that require load swing to be minimized.

(c) Crane controls for a motorized boom shall have a cushioned start device or other controlled acceleration means.

(d) A cushioned start device shall be used for the following applications:

(1) single-speed drives operating at greater than 100 ft/min

(2) two-speed drives operating at greater than 100 ft/min that do not use a time delay between the two speeds

(e) Standard cushioned start devices are as follows:

(1) solid-state reduced-torque starters, which provide for the adjustment of the initial torque upon starting and adjustment of the time for reaching full motor torque

(2) ballast resistors, which limit the initial torque upon starting when the resistor is in an unheated condition

(f) A nonelectrical cushioned start device, such as a fluid coupling, may also be used to minimize load swing.

CM-4.1.1.1.3 Time Delays

(a) All two-speed AC magnetic controls without cushioned starting should be provided with a time delay between the speed steps.

(b) All variable-speed AC magnetic controls shall be provided with time delays between the speed steps as follows:

(1) For a three-step control, a time delay shall be provided between the last two speed steps.

(2) For either a four-step or five-step control, two time delays shall be provided between the last three speed steps.

CM-4.1.1.1.4 Contactors

(a) Reversing and Speed-Stepping Contactors. The minimum NEMA size of magnetic contactors shall be in accordance with Table CM-4.1.1.1.4-1 for AC wound rotor motors, Table CM-4.1.1.1.4-2 for AC squirrel-cage motors, and Table CM-4.1.1.1.4-3 for DC motors.

Wound rotor primary contactors shall be selected to be not less than the current and horsepower ratings. Contactors can have continuous and intermittent ratings. Wound rotor secondary contactors shall be sized such that the contactor's intermittent rating is not less than the motor full-load secondary current. The ampere intermittent rating of a three-pole secondary contactor with poles in delta shall be $1\frac{1}{2}$ times the contactor's wound rotor intermittent rating.

(b) Mainline Magnetic Contactors. When required, mainline magnetic contactors shall be sized in accordance with Table CM-4.1.1.1.4-4 for AC contactors and Table CM-4.1.1.1.4-5 for DC contactors. The size shall not be less than the rating of the largest primary contactor used on any one motion.

(c) Definite-Purpose Contactors. Unless noted otherwise by the owner, definite-purpose contactors specifically rated for crane and hoist duty service may be used for service classes A, B, and C in lieu of NEMA-rated contactors, provided the application does not exceed the contactor manufacturer's published ratings.

CM-4.1.1.1.5 Resistors

(a) Variable-speed AC magnetic controls that require the use of resistors in the secondary circuit of the wound rotor motor shall be as follows:

(1) not less than NEMA Class 150 Series for service classes A, B, and C

(2) not less than NEMA Class 160 Series for service classes D, E, and F

(b) Additional considerations for increasing the resistor class are operating conditions, such as sustained slow-speed operation.

(c) Secondary resistors are rated and classified according to the amount of time they can be in use and the percent of full-load current in the secondary circuit when on the first point of the variable-speed control. Table CM-4.1.1.1.5-1 shows the standard NEMA crane-service resistor classifications based on current, torque, and duty cycle.

(d) All resistors shall be guarded to prevent inadvertent contact.

(e) All resistor enclosures shall be ventilated or sized to dissipate heat.

CM-4.1.1.1.6 AC Variable-Frequency Drives. The general requirements are as follows:

(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 or motors.

(b) Control shall include, as a minimum, protection against the following conditions:

(1) output phase loss

(2) undervoltage

(3) overvoltage

(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 crane or jib power supply and electronic equipment shall be protected from detrimental effects due to harmonic and electromagnetic interference (EMI) or radio frequency interference emissions produced by inverters.

Table CM-4.1.1.1.4-1
AC Contactor Ratings for AC Wound Rotor Motors

Size of AC Contactor	8-hr Open Rating, A	Maximum Intermittent Rating		
			hp at	
		A	250 V	460 V and 575 V
0	20	20	3	5
1	30	30	$7\frac{1}{2}$	10
2	50	67	20	40
3	100	133	40	80

GENERAL NOTE: AC contactor ratings for AC wound rotor motors are from CMAA 74-2020.

Table CM-4.1.1.1.4-2
AC Contactor Ratings for AC Squirrel-Cage Motors

Size of AC Contactor	Maximum Intermittent Rating, hp, at 230 V	460 V and 575 V
0	3	5
1	$7\frac{1}{2}$	10
2	15	25 [Note (1)]
3	30 [Note (1)]	50 [Note (1)]

GENERAL NOTE: AC contactor ratings for AC squirrel-cage motors are from CMAA 74-2020.

NOTE: (1) Squirrel-cage motors over 20 hp are not normally used for crane motions.

Table CM-4.1.1.1.4-3
DC Contactor Ratings for DC Motors (230 V to 250 V DC)

Size of DC Contactor	8-hr Open Rating, A	Maximum Intermittent Rating A	hp
1	25	30	$7\frac{1}{2}$
2	50	67	15
3	100	133	35

GENERAL NOTE: DC contactor ratings for DC motors are from CMAA 74-2020.

Table CM-4.1.1.1.4-4
AC Contactor Ratings for Mainline Service

Size of Contactor	8-hr Open Rating, A	Maximum Intermittent Duty Rating, A	Maximum Total Motor Horsepower		Maximum Horsepower for Any Motion	
			230 V	460 V and 575 V	230 V	460 V and 575 V
0	20	20	6	6	3	5
1	30	30	10	20	$7\frac{1}{2}$	10
2	50	67	30	60	20	40
3	100	133	63	125	40	80

GENERAL NOTE: AC contactor ratings for mainline service are from CMAA 74-2020.

Table CM-4.1.1.1.4-5
DC Contactor Ratings for Mainline Service (230 V to 250 V DC)

Size of Contactor	8-hr Open Rating, A	Maximum Intermittent Duty Rating, A	Maximum Total Motor Horsepower	Maximum Horsepower for Any Motion
1	25	30	10	$7\frac{1}{2}$
2	50	67	22	15
3	100	133	55	35

GENERAL NOTE: DC contactor ratings for mainline service are from CMAA 74-2020.

Table CM-4.1.1.1.5-1
NEMA Resistor Classification

Approximate Percentage of Full Load Current on First Point	Starting Torque in Percentage of Full Load Torque		Class Number According to Duty Cycle			
	1 Phase Starting	3 Phase Starting	15 sec out of 60 sec	15 sec out of 45 sec	15 sec out of 30 sec	Continuous Duty
25	15	25	151	161	171	91
50	30	50	152	162	172	92
70	40	70	153	163	173	93
100	55	100	154	164	174	94

CM-4.1.1.2 Motors

CM-4.1.1.2.1 General

(a) DC Motors. DC motors shall be in accordance with either NEMA MG-1 or AISE Standard No.1.

(b) AC Motors

(1) Definite Purpose Inverter-Fed Motors. AC squirrel-cage motors applied to VFDs shall be specifically designed for inverter duty and shall conform to NEMA MG-1, Part 31, or another standard as approved by the owner.

(2) Definite Purpose Wound Rotor Induction Motors. AC-wound rotor motors shall conform to NEMA MG-1, Parts 18.501 through 18.520.

(3) Other AC Motors. All other AC motors not already described shall conform to NEMA MG-1.

(c) Enclosures and Time Ratings. All AC or DC motors shall have enclosures and time ratings as required for the duty and environmental conditions.

CM-4.1.1.2.2 Motor Voltage

(a) Rated Voltage

(1) Standard rated motor voltage and the corresponding nominal system voltage shall be in accordance with Table CM-4.1.1.2.2-1.

(2) For nominal system voltage other than shown in Table CM-4.1.1.2.2-1, the rated motor voltage should not be less than 95% nor more than 100% of the nominal system voltage.

Table CM-4.1.1.2.2-1
Standard Rated Motor Voltages

Power Supply	Nominal System, V	Rated Motor Voltages, V	Permissible Motor Operating Range, V
AC, single phase, 60 Hz	120	115	104 to 126
	240	230	207 to 253
AC, polyphase, 60 Hz	208	200	180 to 220
	240	230	207 to 253
	480	460	414 to 506
	600	575	518 to 632
AC, polyphase, 50 Hz	208	200	180 to 220
	230	220	198 to 242
	400	380	342 to 418
DC	125	115	104 to 126
	125	120	108 to 132
	250	230	207 to 253
	250	240	216 to 264

(b) Variation from Rated Voltage

(1) All AC induction motors with rated frequency and balanced voltage shall be capable of accelerating and running with the rated hook load at ±10% of rated motor voltage, but not necessarily at rated voltage performance values.

(2) Operation at reduced voltage may result in unsatisfactory drive performance with rated hook load, such as reduced speed, slower acceleration, increased motor current, noise, and heating.

(3) Operation at elevated voltages may result in unsatisfactory operation, such as excessive torques.

(c) Voltage Unbalance. AC polyphase motors shall be capable of accelerating and running with rated hook load when the voltage unbalance at the motor terminals does not exceed 1%. Performance will not necessarily be the same as when the motor is operating with a balanced voltage at the motor terminals.

CM-4.1.1.2.3 Motor Time Rating. The motor time rating shall result in operation complying with the specified performance as defined in Section GR-3, taking into consideration any supplemental requirements specified by the owner.

(a) Minimum Time Ratings. Single-speed, two-speed, and variable-speed motors shall be rated on no less than a 30-min basis under rated load, with the temperature rise in accordance with the class of insulation and enclosure used. The low-speed winding of a two-speed motor may be rated less than 30 min, and the lower stepping speeds of a variable-speed control will have a substantially lower operating time.

(b) Adjustments for Unusual Conditions. Under unusual conditions, such as abnormal inching or jogging requirements; short, repeated travel drive movements; altitudes more than 3,300 ft above sea level; and abnormal ambient temperatures, the motor time rating shall be increased accordingly.

CM-4.1.1.2.4 Traverse Motor Size Selection. The traverse motor rating is basically the mechanical horsepower with considerations for the effect of control and ambient temperature.

(a) Required Motor Horsepower, Indoor Cranes

(1) The bridge motor shall be selected so that the horsepower rating, HP, is not less than that given by eq. (CM-4-1):

$$\mathrm{HP} = K_a W V K_s \tag{CM-4-1}$$

where

K_a = acceleration factor for type of motor used [see eq. (CM-4-2)]

K_s = service factor, which accounts for the type of drive and duty cycle
= 1.0 (crane class A, class B, or class C) for AC inverter, AC magnetic, and DC adjustable-voltage controls
= 1.1 (crane class D) for AC inverter, AC magnetic, and DC adjustable-voltage controls

NOTE: For controls other than AC inverter, AC magnetic, and DC adjustable-voltage controls, consult the control manufacturer.

V = rated drive speed, ft/min

W = total weight to be moved, including all dead and live loads, ton

The acceleration factor, K_a, used in eq. (CM-4-1) is determined by the following equations:

$$K_a = \frac{f + \dfrac{2000_a C_r}{gE}}{33{,}000 K_t} \times \frac{N_r}{N_f} \tag{CM-4-2}$$

$$C_r = 1.05 + \frac{a}{7.5} \tag{CM-4-3}$$

where

a = average or equivalent uniform acceleration rate, ft/sec^2, up to rated motor rpm (see Tables CM-4.1.1.2.4-1 and CM-4.1.1.2.4-2)

C_r = rotational inertia factor for equipment governed by this Standard

E = mechanical efficiency of drive machinery expressed as a per-unit decimal (see Table CM-4.1.1.2.4-3)

f = rolling friction of drive, including transmission losses, lb/ton (see Table CM-4.1.1.2.4-4)

g = 32.2 ft/sec^2

K_t = equivalent steady-state torque relative to rated motor torque, which results in accelerating up to rated motor rpm, N_r, in the same time as the actual variable-torque speed characteristic used (see Table CM-4.1.1.2.4-5 for standard values of K_t)

N_f = speed of free-running motor, rpm, when driving at the rated drive speed, V

N_r = rated speed of motor at full load, rpm

(2) Latitude is permitted in selecting the nearest rated motor horsepower over or 5% under the required horsepower to use commercially available motors. In either case, consideration shall be given to proper performance of the drive.

(b) Required Motor Horsepower, Outdoor Cranes

(1) Compute the free-running bridge motor horsepower (HPF) at rated load and rated speed, neglecting any wind load, using eq. (CM-4-4):

$$\mathrm{HPF} = \frac{WVf}{33{,}000} \tag{CM-4-4}$$

where

f = friction factor, lb/ton (see Table CM-4.1.1.2.4-4)

V = full-load speed, ft/min

W = full-load weight to be accelerated, ton

(2) Compute the free-running bridge motor horsepower due to wind force only (HP_w) using eq. (CM-4-5):

$$\mathrm{HP}_w = \frac{P \times \text{wind area} \times V}{33{,}000E} \tag{CM-4-5}$$

where

E = bridge drive mechanical efficiency

P = wind pressure, lb/ft^2

= $0.00256(V_w)^2$, where V_w is the wind velocity, mph

= 5 lb/ft^2 if V_w is unspecified

wind area = effective crane surface area exposed to wind (as computed in Section CM-2), ft^2

(3) The bridge drive motor shall be selected so that its horsepower rating is not less than the indoor horsepower rating required by (a)(1) or as given by the following equation, whichever is greater:

$$\text{required motor horsepower} = 0.75(\mathrm{HPF} + \mathrm{HP}_w)K_s$$

Table CM-4.1.1.2.4-1
Standard Maximum Acceleration Rate to Prevent Wheel Skidding

% of Driven Wheels	Maximum Acceleration Rate to Prevent Wheel Skidding, ft/sec^2 [Notes (1), (2)]	
	Dry Rails [Note (3)]	Wet Rails [Note (4)]
100	4.8	2.9
50	2.4	1.5
33.33	1.6	1.0
25	1.2	0.7
16.67	0.8	0.5

NOTES:
(1) The maximum acceleration rates to prevent wheel skidding are from CMAA 74-2020.
(2) The values given are based on the peak acceleration torque being equal to 1.33 times the average acceleration torque.
(3) Maximum acceleration rates for dry rails are based on a 0.2 coefficient of friction.
(4) Maximum acceleration rates for wet rails are based on a 0.12 coefficient of friction.

Table CM-4.1.1.2.4-2
Standard Bridge Motion Acceleration Rates

Free-Running Full-Load Speed		Acceleration Rate, a, for AC or DC Motors, ft/sec^2 [Notes (1)–(3)]
ft/min	ft/sec	
60	1.0	0.25 min.
120	2.0	0.25–0.80
180	3.0	0.30–1.0
240	4.0	0.40–1.0
300	5.0	0.50–1.1

NOTES:
(1) The standard bridge motion acceleration rates are from CMAA 74-2020.
(2) The actual acceleration rates shall be selected to account for proper performance, including such items as acceleration time, free-running time, motor and resistor heating, duty cycle, load-spotting capability, and hook swing. The acceleration rates shall not exceed the values shown in Table CM-4.1.1.2.4-3. To avoid wheel skidding, the acceleration rate should not exceed the values shown in Table CM-4.1.1.2.4-1.
(3) For DC series motors, the acceleration rate, a, is the value occurring while the motor is operating on series resistors. This is in the range of 50% to 80% of the free-running speed, N_f.

Table CM-4.1.1.2.4-3
Mechanical Efficiency, *E*, of Drive Machinery

Bearings	E [Notes (1), (2)]
Antifriction	0.97
Sleeve	0.93

NOTES:
(1) The mechanical efficiency, E, of drive machinery is from CMAA 74-2020.
(2) The values of gear efficiency shown apply primarily to spur, herringbone, and helical gearing, and are not intended for special cases such as worm gearing, friction drives, or chain drives.

Table CM-4.1.1.2.4-4
Standard Values for Friction Factor, *f*, for Bridges With Metallic Wheels and Antifriction Bearings

	f, lb/ton [Notes (1)-(3)]	
Wheel Diameter, in.	Top Running	Under Running
18	15	...
15	15	18
12	15	18
10	15	18
8	16	20
6	16	20
5	18	22
4	20	24

NOTES:
(1) The standard values for friction factor, *f*, are from CMAA 74.
(2) For cranes equipped with sleeve bearings of normal proportions, a friction factor of 24 lb/ton may be used.
(3) The friction factors may require modification for other variables, such as low-efficiency worm gearing, nonmetallic wheels, special bearings, and unusual rail conditions.

Table CM-4.1.1.2.4-5
Standard Values of Accelerating Torque Factor, K_t

Type of Motor	Type of Control	K_t [Notes (1), (2)]
AC wound rotor	Contactor-resistor	1.3–1.5 [Note (3)]
AC wound rotor	Static stepless	1.3–1.5 [Note (3)]
AC squirrel cage	Ballast resistor	1.3
AC inverter	Inverter	1.5
DC shunt wound	Adjustable voltage	1.5
DC series wound	Contactor-resistor	1.35

NOTES:
(1) The standard values of accelerating torque factor, K_t, are from CMAA 74.
(2) K_t is a function of control and resistor design.
(3) The low end of the range should be used for applications with permanent slip resistance.

(4) The following items shall be considered in the overall bridge drive design to ensure proper operation under all specified load and wind conditions:

(-a) proper speed control, acceleration, and braking without wind

(-b) ability of control to reach full-speed mode of operation against wind

(-c) bridge speed at any control point when traveling with the wind, not to exceed the amount resulting in the maximum safe speed of the bridge drive machinery

(-d) avoidance of wheel skidding that could likely occur under no load, low-percent driven wheels, and wind conditions

(-e) sufficient braking means to maintain the bridge-braking requirements

(c) Motor Selection Versus Drive Gear Ratio

(1) The drive gear ratio is computed by eq. (CM-4-6):

$$\text{bridge drive gear ratio} = \frac{N_f D_w \pi 12}{V} \qquad \text{(CM-4-6)}$$

where

D_w = wheel tread diameter, in.

N_f = speed of free-running motor, rpm, after the drive has accelerated, with rated load, to the steady-state speed, V. The value of N_f is established from the motor control speed–torque curves at the free-running horsepower, HPF).

V = specified full-load travel drive speed, ft/min

(2) Variations from the calculated gear ratio are permissible to facilitate the use of standard available ratios, provided that motor heating and operational performance are not adversely affected. The actual full-load drive speed may vary a maximum of ±10% from the specified full-load speed.

CM-4.1.1.3 Brakes. When electric brakes are used, brake selection, sizing, and design shall be in accordance with the brake requirements of ASME B30.17, as applicable. The requirements of para. CM-3.1.3.2 shall also be met.

CM-4.1.1.3.1 Electrical Operating and Excitation Systems

(a) The electrical operating and excitation systems shall have a thermal rating for the frequency and duration of the specified operations. The thermal time rating shall equal or exceed the corresponding drive-motor time rating.

(b) Any electrical traverse-drive brake used only for emergency stop on power loss, or set by operator choice, shall have a coil thermal rating for continuous duty.

(c) Brakes with DC shunt coils shall release at 80% and operate without overheating at 110% of the rated excitation system voltage.

(d) Brakes with AC coils shall release at 85% and operate without overheating at 110% of the rated excitation system voltage.

CM-4.1.1.3.2 Parking Brakes. Parking brakes shall be automatically applied. When two friction brakes are used on a single drive, a time delay means shall be provided to prevent simultaneous application of both brakes.

CM-4.1.1.4 Disconnect and Protective Devices

CM-4.1.1.4.1 Disconnects. All disconnects shall be in accordance with the requirements of NPFA 70, Article 610.

(a) Main Manual Crane Disconnect

(1) All motorized cranes and manually operated cranes with either an electric hoist or motorized trolley shall be furnished with a current-rated circuit

breaker or motor-rated switch, lockable in the open position, in the leads from the runway contact conductors or other power supply.

(2) On all manually operated cranes with either an electric hoist or motorized trolley, the main manual crane disconnect may be deleted, provided all the following criteria are met:

(-a) the unit is floor controlled

(-b) the unit is in view of the power supply disconnect

(-c) no fixed work platform has been provided for servicing the unit

(3) The continuous ampere rating of the main manual disconnect shall not be less than 50% of the combined short-time rating of the motors nor less than 75% of the sum of the short-time rating of the motors required for any single motion.

(b) Additional Disconnects. Where the main manual disconnecting means is not readily accessible from the crane operating station, a means shall be provided at the operating station to open the power circuit to all motors of the crane. Although manually operated rope disconnects are available, the most common disconnect for this application is a mainline magnetic disconnect, where a control circuit opens a mainline magnetic contactor (see para. CM-4.1.1.1.4 for contactor ratings).

CM-4.1.1.4.2 Protective Devices

(a) Crane Overcurrent Protection. The crane shall be protected by a main overcurrent device in accordance with NPFA 70, Article 610. In many cases, the main manual disconnect and crane overcurrent devices are furnished as a single unit, being either a circuit breaker or fused disconnect.

(b) Branch Circuit Overcurrent Protection. Motor branch circuits shall be protected by fuses or inverse-time circuit breakers in accordance with NPFA 70, Article 610.

(c) Branch Circuit Overload Protection. Each motor, motor control, and branch circuit conductor shall be protected from overload in accordance with NFPA 70, Article 610.

(d) Undervoltage Protection. Undervoltage protection shall be provided as a function of each motor controller, an enclosed protective panel, a magnetic mainline contactor, or a manual magnetic disconnect switch.

(e) Control Circuits. Control circuits shall be protected in accordance with NFPA 70, Article 610.

CM-4.1.1.4.3 Control. Control shall include a separate disconnecting means for each crane or jib motion.

CM-4.1.1.5 Operator Stations and Controllers. The operator station shall use pendant push-button controllers, cab-operated master-switch controllers, or radio-transmitter lever-switch controllers. One or more operator stations may be provided, using either the same or different types of controllers, as required by the owner. The control station shall be clearly marked to indicate the function of the control device and indicator. The type of operator station and its location shall be specified by the owner.

CM-4.1.1.5.1 Pendant Pushbutton Controllers. Pendant push-button controllers shall meet the following requirements:

(a) The arrangement of the pendant push buttons shall conform to either Figure CM-4.1.1.5.1-1 or the owner's specified arrangement. The relative arrangements of the push buttons should be standardized at each facility.

(b) Push buttons shall return to the OFF position when pressure is released by the crane operator.

(c) Pendant stations shall have a grounding conductor between a ground terminal in the station and the crane.

(d) The maximum voltage in the pendant push-button stations shall be 150 V AC or 300 V DC.

(e) Push buttons shall be guarded or shrouded to prevent accidental actuation of crane motions.

(f) Pendant push-button stations shall be supported in a manner that will protect the electrical conductors against strain.

(g) The minimum wire size of multiconductor flexible cords used for pendant push-button stations shall be number 16 American Wire Gauge (AWG) unless otherwise permitted by NFPA 70, Article 610.

(h) Pendant control stations shall be constructed to prevent electrical shock.

(i) The location of the pendant push-button station controllers shall be one of the following:

(1) suspended from the hoist and trolley when the bridge, jib, or monorail control is shared

(2) suspended from a festooned messenger track system

(3) suspended from a single point off the structure

(4) remote-mounted off the crane

CM-4.1.1.5.2 Cab-Operated Master-Switch Controllers. Cab-operated master-switch controllers shall meet the following requirements:

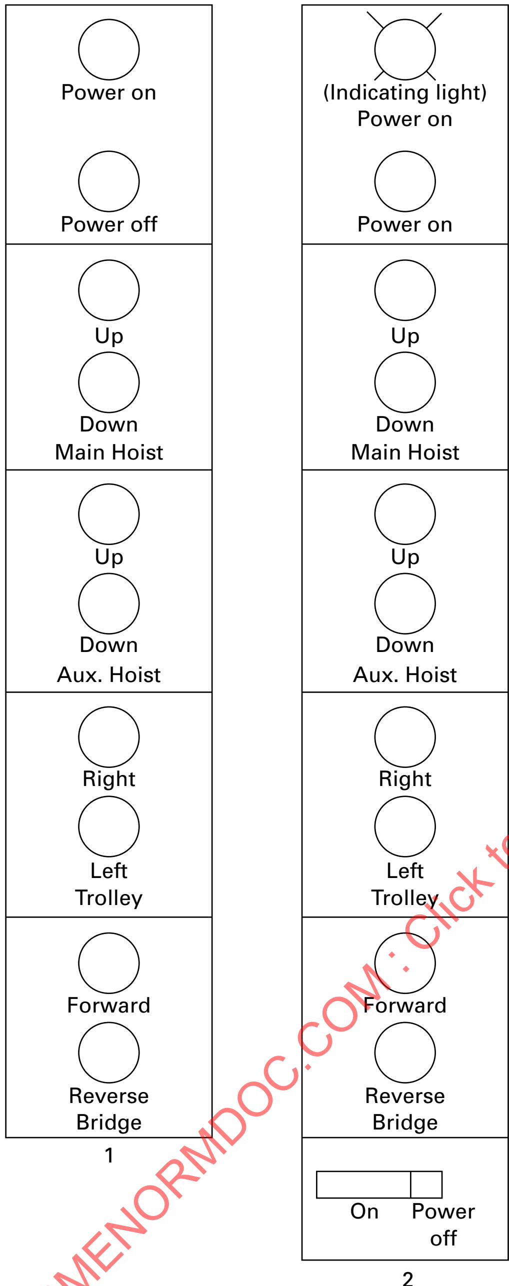
(a) The arrangement of cab master switches shall conform to either Figure CM-4.1.1.5.2-1 or the owner's specified arrangement. Inappropriate controllers shall be deleted. The relative arrangement of the master switches should be standardized at each owner's location.

(b) Master switches shall be within reach of the operator.

(c) Cab master switches shall be provided with a notch or spring-return arrangement latch that in the OFF position prevents the handle from being inadvertently moved to the ON position.

(d) The movement of each switch handle should be in the same direction as the resultant movement of the load.

Figure CM-4.1.1.5.1-1
Arrangement of Pendant Push-Button Controllers



(e) Cranes furnished with skeleton (dummy) cabs are operated by either a pendant push-button station or radio transmitter and therefore do not require master switches unless otherwise required by the owner.

CM-4.1.1.5.3 Radio Transmitter Lever-Switch Controllers. Radio transmitter lever-switch controllers shall meet the following requirements:

(a) The arrangement of the radio transmitter lever switches shall conform to either Figure CM-4.1.1.5.3-1 or the owner's specified arrangement. The relative arrangements of the lever switches should be standardized at each owner's location.

(b) For a radio transmitter lever-switch controller to start and maintain a crane motion, there must be a permissive radio signal in addition to a crane motion signal.

CM-4.1.1.6 Electrical Enclosures. Control enclosures, unless otherwise specified by the owner, shall be suitable for the owner-specified environmental conditions of service. Enclosure types, as defined by NEMA, include, but are not limited to, the following:

(a) NEMA Type 1: general purpose for indoor applications

(b) NEMA Type 3: watertight, dust-tight, and sleet (ice) resistant; outdoor

(c) NEMA Type 3R: rainproof and sleet resistant; outdoor

(d) NEMA Type 4: watertight and dust-tight; indoor and outdoor

(e) NEMA Type 4X: watertight, dust-tight, and corrosion resistant; indoor and outdoor

(f) NEMA Type 7: Class I, groups A, B, C, and D; indoor hazardous locations (explosive atmosphere)

(g) NEMA Type 9: Class II, groups E, F, and G; indoor hazardous locations (explosive atmosphere)

(h) NEMA Type 12: industrial use, dust-tight, and drip-tight; indoor

CM-4.1.1.7 Current Conductor Systems

CM-4.1.1.7.1 Categories of Conductor Systems. Conductor systems shall be considered in the following three general categories:

(a) Runway Systems. Runway systems include conductors and the components necessary to connect power from the building to the crane.

(b) Bridge Systems. Bridge systems include the conductors and the components necessary to connect power from the bridge to the trolley.

(c) Auxiliary Systems. Auxiliary systems include pendant push-button, communication, remote control, and instrumentation cables.

Figure CM-4.1.1.5.2-1
Arrangement of Cab Master-Switch Controllers

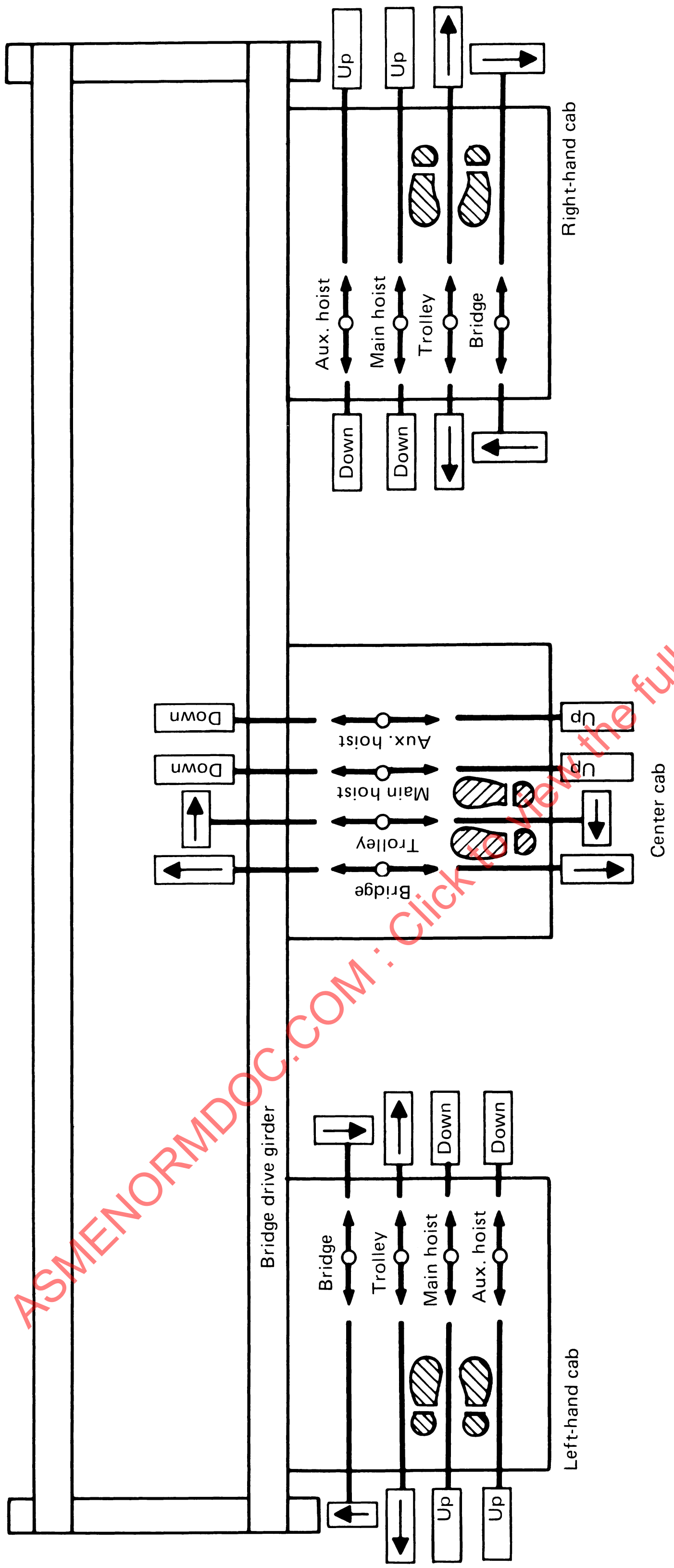
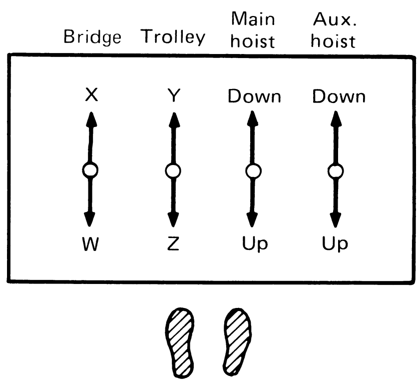


Figure CM-4.1.1.5.3-1
Arrangement of Radio-Transmitter Lever-Switch Controllers



CM-4.1.1.7.2 Conductor System Types

(a) When AC variable frequency controls are used, the runway and the bridge conductor systems shall include a grounding conductor.

(b) Standard types of conductor systems are as follows. See Figure CM-4.1.1.7.2-1 for examples.

(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 systems that use AC variable-frequency drives or DC motor drives, there shall be at least two spring-loaded contact shoes per phase on the mainline 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 insulated taut wire system is not recommended on new applications due to inherent safety issues.

While taut wire arrangements are present on many existing systems, the use of an insulated 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 that is played out off 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.

CM-4.1.1.7.3 Conductor System Design

(a) Current conductors shall have sufficient ampacity to carry the required current to the crane or cranes when the crane or cranes are operating at the rated load. The conductor ratings shall be selected in accordance with NFPA 70, Article 610. For manufactured conductor systems with published ampacities, the intermittent ratings may be used. The ampacities of fixed loads, such as heating, lighting, and air conditioning, may be computed as 2.25 times their total, which will permit the application of intermittent ampacity ratings for use with continuous fixed loads.

(b) The type of runway conductor system shall be suitable for the application and environmental conditions and shall be approved by the owner since it interfaces with the building structure. See also criteria of para. CM-4.1.2.

(c) The type of bridge conductor and auxiliary conductor systems shall be suitable for the application and environment.

(d) Bridge and runway conductors shall use a separate ground conductor.

(e) Runway contact conductors shall be enclosed or guarded.

(f) Bridge contact conductors shall be enclosed, guarded, or located in a manner such that persons cannot inadvertently touch energized current-carrying parts.

(g) Bridge and runway contact conductors shall use tandem collectors.

(h) All sections of contact conductors shall be mechanically joined to provide a continuous electrical connection, except for the use of required expansion joints and jumper cables.

(i) The type and location of runway system conductors shall be specified by the owner.

CM-4.1.1.8 Warning Devices

(a) On cab-operated cranes and remote-operated cranes, a gong or other warning means shall be provided for each crane equipped with a power-traveling mechanism.

(b) On pendant push-button-controlled cranes, a gong or other warning means shall be provided if required by the owner.

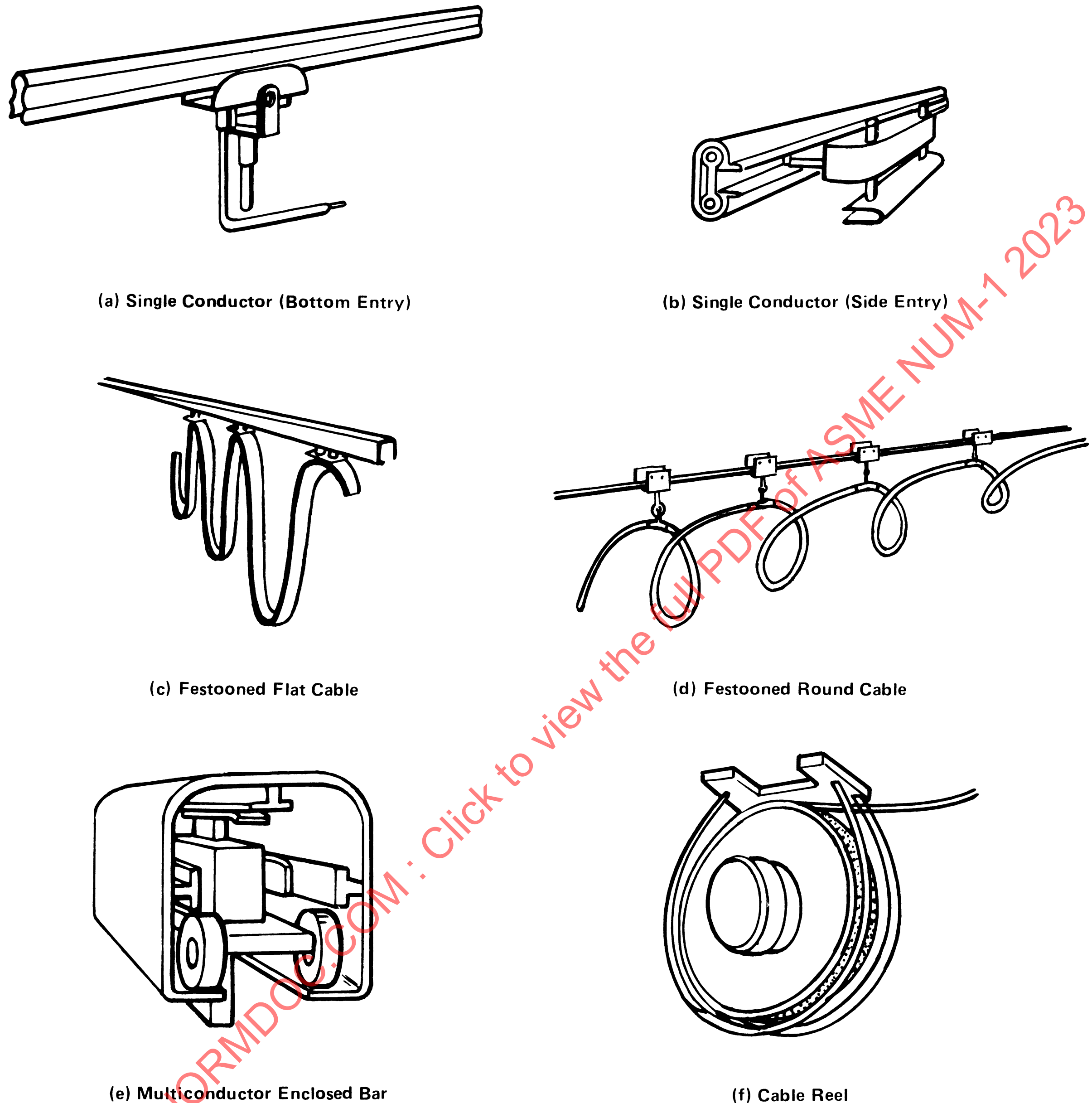
CM-4.1.1.9 Auxiliary Electrical Equipment. When required by the owner, the following auxiliary equipment shall be provided:

(a) travel limit switches

(b) heating, ventilating, and air conditioning

(c) convenience outlets

Figure CM-4.1.1.7.2-1
Various Styles of Conductor System Types



CM-4.1.2 Wiring Materials and Methods

(a) The wiring system shall meet the requirements of NFPA 70, Article 610, as supplemented by para. CM-4.1.2.

(b) The provisions of para. CM-4.1.2 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 (e.g., 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 matchmarked for 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 to which it applies.

CM-4.1.2.1 Wiring Materials

CM-4.1.2.1.1 Conductors

(a) Individual conductors, including those in multiconductor cables, shall have a maximum operating temperature rating not less than 75°C.

(b) Multiconductor cable may be used for wiring the crane. The cable shall comply with the requirements of NFPA 70. Flexible service cable shall be used when required for the application, such as in a festooned flexible continuous conductor system.

(c) Minimum sizes of conductors (excluding electronics) shall be as follows:

(1) number 14 AWG for power and lighting circuits

(2) number 16 AWG for control circuits

(d) 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

(e) Color coding, if required by the owner, shall be in accordance with NEMA ICS 1.

(f) All control conductors and cables used with AC inverter-type controls and having operating voltages less than 110 V shall be of the shielded type.

CM-4.1.2.1.2 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 para. CM-4.1.2.1.2 or as approved by the owner.

(b) Short lengths of open conductors shall be permitted at collectors and within enclosures or guards for resistors and transformers.

(c) Conduit smaller than $^3/_4$ in. diameter trade size shall not be used.

(d) 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.

(e) Connections to moving parts (bridge to trolley, bridge or trolley to pendant push-button station) may be made by flexible cable not enclosed in conduit. Where flexible cable is used, some form of strain relief shall be provided.

(f) Conduit shall be rigidly attached to the crane by conduit supports.

CM-4.1.2.2 Wiring Methods

(a) All conductors shall be identified at each termination by a marking that corresponds 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.

(c) Pressure-type connectors shall be provided on all wires connected to terminals not equipped with a 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, provided the termination point is designed to accept two connections.

(e) Panel wiring shall be routed in a manner that will not interfere with inspection and maintenance of devices.

(f) Conductors to components that could be detrimentally affected by induced EMI shall be selected and installed in a manner to reduce such effects. Examples for methods to reduce the effects include the following:

(1) Use individually shielded twisted-pair conductors for tachometers or encoder connections.

(2) Route such conductors through a separate conduit.

(3) Refrain from splicing connections.

CM-4.1.3 Seismic

Analyses shall be performed to confirm that electrical components that would damage safety-related equipment if dislodged will remain in place during a seismic event.

CM-4.1.4 Allowable stresses for Fasteners

Fasteners for mounting electrical components, such as control enclosures, shall comply with the requirements of para. CM-3.1.2.3.4.

CM-4.2 ADDITIONAL DESIGN REQUIREMENTS SPECIFIC TO JIB CRANES

CM-4.2.1 General

(a) Except as noted in (b), the information in para. CM-4.2.2 applies to jib cranes that have motor-operated boom rotation.

(b) For jib cranes that do not have a motor-operated boom but use either an electrically operated hoist or electrically operated trolley, the information in paras. CM-4.1.1.4, CM-4.1.1.5, CM-4.1.1.7, CM-4.1.2.1, and CM-4.1.2.2 still applies.

CM-4.2.2 Motors

A jib slew drive motor for a motorized boom shall meet the criteria of para. CM-4.1.1.2 except that the motor rating, which is basically the mechanical horsepower with consideration for the effect of control, shall be sized as follows for indoor and outdoor applications:

(a) Slew Drive Motor Size Selection, Indoor Cranes. The jib slew drive motor shall be selected so that the horsepower rating, HP, is not less than that given by eq. (CM-4-7):

$$\text{HP} = \frac{I_0(N^3)}{(7 \times 10^6)EK_t} \quad \text{(CM-4-7)}$$

where

E = system efficiency
I_o = load moment of inertia, lb-ft^2
= WL × RL^2
K_t = torque factor, which is the equivalent steady-state torque relative to rated motor torque that results in accelerating up to rated motor rpm in the same time as the actual variable-torque speed characteristic of the motor and control characteristic used (see Table CM-4.1.1.2.4-5 for standard values of K_t)
N = rotational speed, rpm
RL = maximum load radius, ft
WL = rated load plus the hoist weight, lb

(b) Slew Drive Motor Size Selection, Outdoor Cranes. The jib slew drive motor shall be selected so that the horsepower rating is not less than that given by the following equation. See also Figure CM-4.2.2-1.

$$\text{total required horsepower} = \text{HP} + \text{HP}_{\text{wind}}$$

where
HP$_{\text{wind}}$ = horsepower required to overcome wind load

$$\text{HP}_{\text{wind}} = \frac{TN}{5{,}250EK_t} \quad \text{(CM-4-8)}$$

and HP, E, K_T, and N are as defined in (a).

The value T is calculated from the following equation:

$$T = \text{PSF}[(A_{\text{boom}})(\text{RB}) + (A_{\text{load}})(\text{RL})]\text{SF}$$

where RL is as defined in (a) and

A_{boom} = projected area of boom, ft^2
A_{load} = projected area of load, ft^2
HB = height of boom, ft
HL = height of load, ft
LB = length of boom, ft
LL = length of load, ft
PSF = operating wind load specified by owner, lb/ft^2
= 5 lb/ft^2 if not specified
= LB × HB
RB = radius to centroid of projected area of boom, ft
= LL × HL
SF = shape factor

(c) Sample Calculation. See Nonmandatory Appendix A, subsection A-1 for a jib slew drive sample calculation and a derivation of the simplified horsepower equation.

CM-4.3 ADDITIONAL DESIGN REQUIREMENTS SPECIFIC TO MONORAIL SYSTEMS

CM-4.3.1 General

The information in para. CM-4.3.2 applies to monorail systems that use either an electrically operated hoist or electrically operated trolley, or that use electrically operated track devices.

CM-4.3.2 Electrical Components

CM-4.3.2.1 Electrically Operated Track Devices

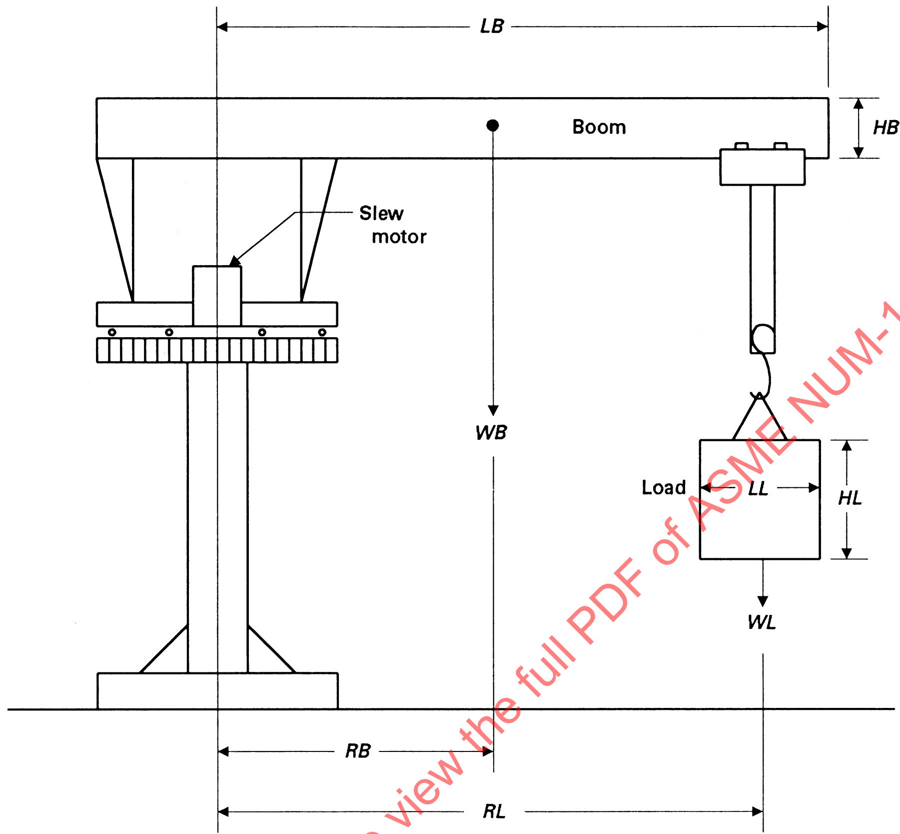
(a) The owner shall specify if track devices are to be electrically operated.

(b) Standard track devices that are electrically operated are as follows:

(1) track switches and turntables
(2) track interlocks
(3) vertical track lift and drop sections
(4) electric baffles

(c) Electric baffles shall be provided as required by ASME B30.17.

Figure CM-4.2.2-1
Slew Drive Motor Size Selection



Legend:
HB = height of boom
HL = height of load
LB = length of boom
LL = length of load
RB = radius to centroid of projected area of boom
RL = maximum load radius
WB = weight of boom
WL = rated load plus the hoist weight

CM-4.3.2.2 Motors. Motors for electrically operated track devices shall meet the criteria of para. CM-4.1.1.2, except that time rating and size selection shall be as required for the specific track device and application.

CM-4.3.2.3 Brakes

(a) Vertical track lift and drop sections shall be furnished with a spring-set friction-type brake having a torque rating of at least 125% of the rated motor torque of the track device hoisting the motor.

(b) Spring-set friction-type brakes shall be in accordance with para. CM-4.1.1.3.

Section CM-5
Pneumatic Requirements, Cranes and Monorails (Type I)

CM-5.1 GENERAL

This Section covers the pneumatic requirements and criteria common to all Type I cranes and monorails. Requirements for hoists are covered under Part HT.

CM-5.2 AIR SUPPLY

Air-operated cranes and monorails shall operate on an air supply that is essentially clean and dry with the pressure at 90 psi, although air systems at 105 psi may be used if accepted by both the owner and hoist manufacturer. Unless specified otherwise, the maximum moisture content of the air shall be 0.002 lb of water per pound of dry air at 60°F and 90 psia, with the maximum solid particulate contamination limited to 25 μ. The owner's main air supply shall be sufficient to accommodate the total air consumption of all air motors, with this consumption rate (in cubic feet per minute) provided by the manufacturer. The owner's main air supply shall include a building-mounted shutoff valve and an adjustable air pressure regulator in the area of the crane or monorail. Additionally, the owner shall provide a relief valve system to prevent excessive air pressure from damaging the crane or monorail.

CM-5.3 AIR MOTORS

Air motors shall be air-driven piston or rotary-vane type and shall be provided with an air inlet connection fitted for the use of air hose assemblies. Also, the air motor shall be provided with an oiler and air filter between the motor and the air inlet connection. The motor shall have the required horsepower to accelerate and traverse the rated load at the specified speed. The motor shall have the capacity to traverse 125% of the rated load. Air motor performance curves shall be furnished.

CM-5.4 ADDITIONAL AIR EQUIPMENT

Air motors shall be furnished with the necessary directional valves, a dump valve operated by a power off or emergency stop button, and a crane- or monorail-mounted regulator and pressure gauge to confirm the pressure at the motor. The air motor exhausts should include an exhaust filter and muffler as determined necessary by the manufacturer or shall be provided as specified by the owner. Mufflers shall be required for indoor applications and shall be such that the motor sound level for each motor shall be 80 db or less when 3 ft from the muffler, unless specified otherwise by the owner.

CM-5.5 AIR MOTOR CONTROLS

Air-operated cranes and monorails shall have pendant, pull, or rod control as specified by the owner. Control actuators shall automatically return to the OFF position when released. Unless otherwise specified by the owner, the control station shall be 3 ft to 5 ft above the specified operating level. Criteria for the various types of air motor controls are listed in paras. CM-5.5.1 through CM-5.5.3.

CM-5.5.1 Pendant Control

The pendant control station shall be supported to protect the pneumatic hoses and connections against strain. The pendant control station shall be clearly marked to indicate the function of each actuator. The control motion actuators may be either push buttons or levers.

CM-5.5.2 Pull Control

Pull control shall consist of two pull chains or cords each with a suitable handle clearly marked for direction.

CM-5.5.3 Rod Control

Rod control shall permit control of crane or monorail (air-operated) motion by linear or rotary movement of the rod handle, or a combination of both. The rod handle shall be clearly marked for direction of motion.

Section CM-6
Marking, Cranes and Monorails (Types I and II)

CM-6.1 CRANE AND MONORAIL MARKING

CM-6.1.1 General

(a) The rated load shall be marked on each side of the crane bridge, jib boom, and monorail, with monorail markings at intervals so as to always be visible from the operating floor.

(b) Top-running bridge and gantry cranes, including wall cranes, shall have additional markings in accordance with ASME B30.17.

(c) Monorails, underhung cranes, and bridge cranes shall have additional markings in accordance with ASME B30.17.

(d) Hoists used on any bridge crane, wall crane, jib crane, or monorail shall be marked in accordance with Part HT.

CM-6.1.2 Type I Cranes and Monorails

(a) For Type I bridge cranes, wall cranes, jib cranes, and monorails, the MCL shall be marked on the bridge beam, jib boom, or monorail in lieu of the rated load. The abbreviation "MCL" shall be part of the marking.

(b) For Type I bridge cranes, wall cranes, jib cranes, and monorails that lift loads in excess of the MCL, the design rated load shall also be marked on the bridge beam, jib boom, or monorail. The abbreviation "DRL" shall be part of the marking.

Section CM-7
Inspection and Testing, Cranes and Monorails (Types I and II)

CM-7.1 GENERAL

The requirements and criteria in Section CM-7 are applicable to all Type I and II cranes and monorails unless specifically stated elsewhere.

CM-7.1.1 Scope and Responsibility

CM-7.1.1.1 Scope. The subparagraphs within para. CM-7.1.1 describe the general inspection and testing requirements for all cranes and monorails beginning prior to manufacture and continuing through delivery, erection, acceptance load testing, and inspection at the erection site. Each crane and monorail shall be examined for compliance with the specified requirements and the approved drawings. This element of inspection shall include a visual examination and dimensional checks.

CM-7.1.1.2 Responsibility. Unless otherwise specified by the owner, the manufacturer is responsible for the performance of all inspection and test requirements as specified herein. The owner shall be permitted to witness inspections and tests as well as any inspections and tests to be performed at the erection site.

CM-7.1.1.3 Documentation. All inspections and tests performed on the crane or monorail, both at the plant and at the site, shall be fully documented in reports with copies furnished to the owner.

CM-7.1.2 Inspection by Seller Before and During Manufacture

The following identifies the specific criteria for the inspections and tests specified by Table CM-2.1.5.1-2.

CM-7.1.2.1 Structural Inspection. Structural components shall be visually and dimensionally inspected for conformance with drawing requirements and specifications.

CM-7.1.2.1.1 Welding

(a) All structural welds shall be visually inspected over their entire lengths. Acceptance criteria of welds and repairs shall be in accordance with AWS D1.1 or AWS D14.1. Nondestructive testing of groove welds shall be in accordance with Table CM-2.1.5.1-2.

(b) Welds whose failure during a seismic event could cause the crane or monorail to fall shall be nondestructively tested.

(1) for butt welds,100% radiographic testing (RT) or ultrasonic testing (UT) in accordance with AWS D1.1 or AWS D14.1. Acceptance criteria shall be in accordance with AWS D1.1 or AWS D14.1.

(2) for other welds, 100% magnetic particle testing (MT) or dye penetrant testing (PT) of each weld 10 in. or less in length; 10% MT or PT of each weld that exceeds 10 in. in length. Technique and acceptance criteria shall be in accordance with AWS D1.1 or AWS D14.1.

(c) Welders and welding procedures shall be qualified or prequalified in accordance with AWS D1.1 or AWS D14.1.

CM-7.1.2.1.2 Drop Weight Testing. Drop weight testing shall be in accordance with ASTM E208. Charpy impact testing shall be in accordance with ASTM A370.

CM-7.1.2.1.3 UT Volumetric Testing

(a) UT volumetric testing and acceptance criteria shall be in accordance with ASTM A435/A435M for plate material.

(b) UT volumetric testing shall be in accordance with ASTM E114 and ASTM A388/A388M for wrought or forged material.

(1) Acceptance criteria for forged material shall be in accordance with the following:

(-a) Straight Beam. A forging or bar shall be unacceptable if the results of straight beam examinations show one or more reflectors that produce indications accompanied by a complete loss of back reflection not associated with or attributable to geometric configurations. Complete loss of back reflection is assumed when the back reflection falls below 5% of full calibration screen height.

(-b) Angle-Beam Rule. A forging or bar shall be unacceptable if the results of angle-beam examinations show one or more reflectors that produce indications exceeding the amplitude reference line from the appropriate calibration notches.

(2) Acceptance criteria for material without parallel surfaces shall be as follows:

(-a) Discontinuity indications in excess of the response from a $\frac{1}{8}$ in. diameter flat-bottomed hole at the estimated discontinuity depth shall not be acceptable.

(-b) Discontinuity indications in excess of the response from a $^3/_{32}$ in. diameter flat-bottomed hole at the estimated discontinuity depth shall not have their indicated centers closer than 1 in.

(-c) Elongated- (stringer-) type defects in excess of 1 in. in length shall not be acceptable if at any point along the length, the discontinuity indication is equal to or greater than the response from a $^3/_{32}$ in. diameter flat-bottomed hole.

CM-7.1.2.1.4 Component Fit-Up. Structural components shall be inspected to ensure that they are properly aligned and fitted without inducing built-in stresses.

CM-7.1.2.1.5 Structural Materials. Material test reports shall be required on structural materials, including seismic restraints, whose failure during a seismic event would cause the crane or monorail to fall.

CM-7.1.2.1.6 Fasteners. Material test reports shall be required on fasteners, including those for seismic restraint, whose failure during a seismic event would cause the crane or monorail to fall.

CM-7.1.2.2 Mechanical Inspection. Mechanical components shall be inspected as specified by the owner.

CM-7.1.2.3 Electrical Inspection.

CM-7.1.2.3.1 Visual Inspection. Inspections shall be performed at the crane or monorail manufacturer's plant (or during field erection if not feasible to perform at the 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 drawings and are properly identified
(e) raceways are properly supported and installed, and raceways to be removed for shipment are properly marked and fitted for field reinstallation
(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 or monorail as established by the 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 or monorail move freely
(k) pendant and festoon cable strain relief are properly installed
(l) overload relay current sensing elements are in accordance with drawings
(m) motor connections are properly made
(n) contactors and electromechanical relays whose armatures are accessible operate freely by hand
(o) electrical enclosures are correct NEMA type and panel door operates properly
(p) motor brushes are properly seated
(q) electrical holding brakes are adjusted to correct torque settings
(r) conductors are identified at each termination and correspond to the schematic diagrams

CM-7.1.2.3.2 Control Software. Desk audits, peer reviews, and static analysis tools and techniques shall be used throughout the development process to verify implementation of design requirements in the source code, with particular attention paid to the implementation of identified safety-critical functions, such as fault detection and safing or correcting logic.

CM-7.1.2.3.3 Operation. Electrical components shall be checked out prior to or during shop tests to ensure that they operate as designed.

CM-7.1.3 Shop Operational Tests

A shop no-load test shall be performed at the crane or monorail manufacturer's facility. Procedures shall be prepared and used by the manufacturer conducting the test. If subsequent manufacturing or associated activities affect the validity of this test or portions thereof, the appropriate portions of the test shall be repeated. Nonconformances found during the testing shall be treated as required by the test procedure.

CM-7.1.3.1 Prerequisites. Before conducting the shop no-load test, the lifting equipment or applicable portions to be tested shall be assembled and wired subject to the following:

(a) The equipment 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.
(c) When testing the operations of mechanical portions of the crane or monorail, the use of a temporary controller is acceptable unless otherwise specified by the owner.
(d) When testing electrical portions of the crane or monorail, they shall be tested with the actual equipment controls unless specifically excepted by the owner.
(e) The assembled crane or monorail shall be square and in alignment, with parts fitted and adjusted properly.

CM-7.1.3.2 Testing

CM-7.1.3.2.1 Mechanical Requirements. As a minimum, the following mechanical functions shall be verified:

(a) Traverse the trolley on the bridge, boom, or monorail; verify interfaces of auxiliary equipment (powered operation is preferred).

(b) Operation of mechanical components shall be verified to meet design criteria.

CM-7.1.3.2.2 Electrical Requirements. A test of the crane or monorail electrical system shall be made to verify proper operation of the controls. For remote-controlled cranes or monorails, the transmitter-receiver system shall be used for this test.

CM-7.1.3.2.3 Software Requirements. For PLC-controlled cranes or monorails, the PLC software shall be installed and used during the test. Software testing (either breadboard or as part of the crane or monorail testing) shall include the following, as a minimum:

(a) hardware, software, and operator input failure mode testing

(b) boundary, out-of-bounds, and boundary-crossing test conditions

(c) input values of zero, zero crossing, and approaching zero from either direction

(d) minimum and maximum input data rates in worst-case configurations to determine system capabilities and responses to these environments

CM-7.1.4 Preparation For Shipment

CM-7.1.4.1 Disassembly. Equipment that has been assembled for shop testing shall be disassembled only as required for shipment to the erection site or specified storage facility.

CM-7.1.4.2 Marking and Tagging. Each item or subassembly shall be marked or tagged with its name and drawing, assembly, and item or subassembly identification. Items disconnected for handling and shipping shall be matchmarked for reassembly at the erection site. Marking shall be accomplished using a method that is not detrimental to the material; e.g., sharp-bottom stamps shall not be used for marking structural components that will be subjected to high stresses.

CM-7.1.4.3 Inspection. Before shipment, all items, assemblies, or subassemblies shall be inspected to ensure that they are complete, undamaged, properly identified, and properly packaged.

CM-7.1.4.4 Packaging. Packaging of items to be shipped shall be as required to provide protection from handling or shipping damage. All items, assemblies, or subassemblies shall be accurately identified and listed in the bill of lading as necessary for receipt inspection at the erection site or storage facility.

CM-7.1.4.5 Receipt Inspection by Owner

CM-7.1.4.5.1 Verification. All items, subassemblies, and assemblies shall be checked against the bill of lading for proper identification and verification of receipt. Discrepancies shall be reported to the transporter and shipper.

CM-7.1.4.5.2 Condition. All items, subassemblies, and assemblies shall be inspected for corrosion, contamination, deterioration, or physical damage resulting from shipment. Damage shall be reported to the shipper.

CM-7.1.4.5.3 Documentation. Receipt of documentation as required by the owner or this Standard, as applicable, shall be verified by the owner.

CM-7.1.5 Storage by Owner Before Erection

CM-7.1.5.1 Preparation for Storage. When receipt inspection of an item has been completed, the item shall be in satisfactory condition for storage. Ensure that pipe caps or covers removed for receipt inspection are replaced, machined surfaces are protected, and crated items have been re-crated (if applicable), in accordance with the owner's requirements governing preparation for shipment and storage.

CM-7.1.5.2 Storage Requirements. Items, assemblies, and subassemblies should be stored in an atmosphere that will provide protection from damage or deterioration from other work or traffic, adverse weather conditions, fires, flooding, etc.

CM-7.1.6 Inspection by Owner at Erection

CM-7.1.6.1 Prerequisites

(a) Inspections or checks, as appropriate, shall be performed to verify that conditions of the installation area conform to specified requirements and that precautions have been taken to prevent conditions that will adversely affect the quality of the item during installation.

(b) Permanent crane runway supports and mountings that will properly interface with the crane shall have been installed.

CM-7.1.6.2 Inspection During Assembly. Inspections of the work areas and the work in progress shall be performed to verify that the crane components are being located, installed, assembled, or connected in compliance with the latest approved-for-construction drawings, this Standard, 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) cleanliness
(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

CM-7.1.6.3 Assembled Inspection. 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 ensure 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) mating parts, such as couplings, are properly positioned
(b) proper greasing or lubrication has been completed
(c) casings, reservoirs, etc., are primed, vented, and filled
(d) control of specified bolting method and the following electrical elements:
(1) electrical connections inspected for good contact and conformance with the wiring diagram
(2) bridge conductor collector system inspected for proper alignment

CM-7.1.7 Site Load Testing

CM-7.1.7.1 Preoperational Testing and Inspection. A preoperational testing and inspection program shall be established to demonstrate that the equipment will perform satisfactorily in service. The preoperational testing shall be performed in accordance with written test procedures that incorporate acceptance criteria. Unless otherwise specified by the owner, the owner or the representative designated by the owner shall
(a) witness the preoperational tests called for by these procedures
(b) furnish all facilities necessary for the performance of such tests
(c) ensure that proper communications are established for control of testing

These testing requirements shall be completed after the equipment has been installed and prior to construction or operational use of the crane or monorail.

CM-7.1.7.2 No-Load Test

CM-7.1.7.2.1 Testing. A no-load test shall be performed to verify the following after the power supply has been verified to be in accordance with equipment specifications:
(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 drives, as applicable, through their respective speed ranges.

CM-7.1.7.2.2 Additional Requirements. While the no-load testing is being performed, the following information shall be recorded or observed:
(a) Electrical (Full-Speed Conditions)
(1) motor volts
(2) motor amperes
(3) motor rotations per minute
(b) Mechanical
(1) noise levels
(2) oil leaks
(3) excessive vibration
(4) clearances per drawings and specifications
(5) gear alignment and engagement
(6) wire rope or chain condition
(c) Structural
(1) overall building clearances
(2) bridge and trolley end approaches
(d) all software faults
(e) components, systems, and features with 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

CM-7.1.7.3 Full-Load Test. The crane or monorail shall be statically loaded at bridge midspan (or end of boom) to 100% (+5%, −0%) of manufacturer's rating. With this load, the crane or monorail shall be operated through all drives for bridge or boom and through all speed ranges to demonstrate speed controls and proper function of limit switches, locking, and safety devices as practical with full load. The hoist shall be verified to stop and hold 100% load while lowering at maximum speed upon loss of power. Opening the mainline magnetic contactor by means of the emergency stop may be used to simulate a loss of power condition. Manually operated load-lowering devices, if supplied, shall be tested.

CM-7.1.7.4 Rated Load Test. After the no-load and full-load tests are completed and prior to use for handling loads, the equipment shall be rated load tested.
(a) The crane or monorail shall receive a rated-load test of 125% (+5%, -0%) of the rated capacity.
(b) The rated-load test shall consist of the following operations as a minimum:
(1) Lift the test load approximately 2 ft and hold the load for a minimum of 5 min to verify no test weight drift.
(2) Transport the test load by means of the trolley (carrier) from one end of the crane bridge, jib, or monorail to the other. The trolley motion shall be smooth and regular. The trolley shall approach the limits of travel

as close as practical if use area restrictions are imposed and based on the test load configuration.

(3) For bridge and gantry cranes, transport the test load by means of the bridge or gantry 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 practical, and in the other direction with the trolley as close to the extreme left-hand end of the crane as practical. The trolley shall approach the limits of travel as close as practical if use area restrictions are imposed and based on the test load configuration.

When cranes operate on more than two runways (multiple-track cranes), the crane shall transport the test load for the full length of the runway with the test load under each of the intermediate tracks.

(4) Verify that the nameplate reflects the load rating per (a) above.

(5) For jib cranes, verify that there is jib boom motion with the trolley located at each end and at the center of the boom.

CM-7.1.7.5 Certification. A written report confirming the equipment has successfully passed the rated-load testing shall be furnished. This report shall be signed by representatives of all parties participating in the test.

CM-7.2 ADDITIONAL INSPECTION AND TESTING REQUIREMENTS SPECIFIC TO UNDERHUNG CRANES

There are no additional inspection and testing requirements specific to underhung cranes.

CM-7.3 ADDITIONAL INSPECTION AND TESTING REQUIREMENTS SPECIFIC TO TOP-RUNNING BRIDGE AND GANTRY CRANES

There are no additional inspection and testing requirements specific to top-running bridge and gantry cranes.

CM-7.4 ADDITIONAL INSPECTION AND TESTING REQUIREMENTS SPECIFIC TO TRAVELING WALL CRANES

CM-7.4.1 General

The requirements of subsection CM-7.1 shall be followed where applicable.

CM-7.4.2 Performance

The following activities shall be performed after installation at the site:

(a) Check the levelness and alignment of the wall crane without load.

(b) Check deflection of the boom with crane loaded to rated capacity and load positioned at maximum distance from support rails or flanges. Deflection shall not exceed the maximum specified in subsection CM-2.4 or by the owner. Verify that the trolley does not drift along the boom at rated load.

(c) Verify proper alignment and engagement of all wheels with support rails or flanges and proper operation through all modes of travel during rated load and no-load conditions.

CM-7.5 ADDITIONAL INSPECTION AND TESTING REQUIREMENTS SPECIFIC TO JIB CRANES

CM-7.5.1 General

The requirements of subsection CM-7.1 shall be followed where applicable.

CM-7.5.2 Performance

The following activities shall be performed after installation at the site:

(a) Check the levelness and alignment of the boom or jib without load.

(b) Check deflection of the boom with rated load applied at maximum distance from wall, mast, or column support. Deflection shall not exceed the maximum specified in subsection CM-2.5. Verify that the trolley does not drift along the boom at rated load.

(c) Verify proper rotation of the jib throughout its full range of travel with the rated load applied at the maximum distance from the wall, mast, or column support as permitted by the test load configuration. Verify that the amount of boom drift under these conditions is acceptable.

CM-7.6 ADDITIONAL INSPECTION AND TESTING REQUIREMENTS SPECIFIC TO MONORAIL SYSTEMS

CM-7.6.1 General

The requirements of subsection CM-7.1 shall be followed where applicable.

CM-7.6.2 Performance

The following site inspection shall be performed as applicable to verify installation:

(a) *Tracks.* Check the following for compliance with the drawings and with subsection CM-2.6:

(1) track levelness

(2) proper location and installation of supports (e.g., hanger rods)

(3) bracing to prevent excessive sway

(4) rail couplings (splice plates)

(5) rail spacing (gaps)

(6) track radii

(7) proper clearances

(8) end stops

(b) Track Switches. Check track switches for

(1) proper alignment and operation

(2) spacing (gaps)

(3) stops or guards on open ends of track and on movable track

(4) means of holding movable track when carrier (trolley) is being moved on it

(5) electric baffles (if provided to prevent load path from interfering with load path of adjacent track)

NOTE: Track switches shall operate only with an unloaded carrier unless the track switches were specified and designed to operate with a loaded carrier.

(c) Track Openers. Check track openers, if provided, for

(1) proper alignment and operation

(2) spacing (gaps)

(3) proper installation of forks or stops to prevent carrier (trolley) from running off open ends of track when movable section is not aligned with the track

(d) Vertical Drop and Lift Sections. Check vertical drop and lift sections for

(1) proper alignment

(2) spacing (gaps)

(3) end stops

(4) clearances

(5) electric baffles (if provided for cab-operated carriers or automatic dispatch carriers)

(e) Clearances. Check clearances of lateral or overhead obstructions for compliance with para. GR-2.1.1.

(f) Locking and Safety Devices. During no-load operational testing, check all locking and safety devices for interlocking mechanisms, track switches, drop sections, and lift sections.

(g) Deflection. Check deflection of track and track components at rated load for compliance with subsection CM-2.6.

(h) Rated Load Testing. During rated load testing, check the trolley for smooth motion in all directions, around all curves, across all rail splices, and through all switch configurations and travel directions. Check for proper structural bracing to prevent excessive sway.

(i) Track Splices and Switches. Check for proper alignment of track splices and switches under load.

PART HT
HOISTS AND TROLLEYS

Section HT-1
Introduction

HT-1.1 GENERAL

As stated in Section GR-1, Type I enhanced safety hoisting equipment is divided into two subtypes: Type IA and Type IB. Part HT specifies the requirements for the subtypes of the following specific hoisting equipment configurations:

(a) powered wire rope hoists (Type IA)
(b) powered wire rope hoists (Type IB)
(c) powered chain hoists (Type IB)
(d) hand-chain hoists (Type IB)

This Standard does not anticipate the use of chain hoists in a Type IA application. If the owner desires a Type IA chain hoist, it shall be provided with safety features and designs equivalent to those of a Type IA wire rope hoist.

This Section of the Standard also covers under-running trolleys (Type IB), either as an independent unit or integral with a hoist. All trolleys are categorized as Type IB and have increased design factors.

Common nondestructive examination (NDE) criteria applicable to the hoists and trolleys of Part HT are addressed under Section HT-7.

Although the Type IA and IB hoist and trolley equipment of Part HT is typically suspended from a Type I crane or monorail as specified under Part CM, this hoist and trolley equipment may also have independent applications, including the mounting of a hoist unit to a stationary structure.

Standard hoist and trolley units, such as those used on a Type II or Type III crane or monorail, are not covered under this Standard. However, standard hoisting equipment used on a Type II crane or monorail shall remain in place during a seismic event and have restraints that ensure this requirement.

The hoists and under-running trolleys of Part HT shall also comply with the following general requirements of Part GR:

- Section GR-2, Environmental Conditions of Service
- Section GR-3, Performance Requirements
- Section GR-4, Coatings and Finishes
- Section GR-5, Quality Assurance

Additional information and criteria are provided in Section GR-1, definitions are provided in Section GR-6, and a list of referenced codes and standards is provided in Section GR-7.

Section HT-2
Powered Wire Rope Hoists (Type IA)

HT-2.1 GENERAL

This Section provides the requirements for powered (electric- or air-operated) Type IA hoists for enhanced safety vertical lifting of freely suspended unguided loads using wire rope as a lifting medium.

A Type IA powered wire rope hoist shall be of a unique design with single-failure-proof features for the hoisting machinery and the hoist reeving.

HT-2.2 EQUIPMENT CONFIGURATIONS (TYPE IA)

(a) The hoisting machinery from the motor to the drum shall be designed to provide assurance that a failure of a single component will not result in the uncontrolled movement of the lifted load. The wire rope drum shell is exempted from this requirement.

(b) Load motion due to failure of one load path of a redundant load path hoist shall be evaluated for facility acceptability.

(c) Figures HT-2.2-1 through HT-2.2-3 provide some block diagrams illustrating examples of Type IA wire rope hoist equipment configurations. These block diagrams show conceptual layouts only. The machinery together with a redundant reeving arrangement shall comply with the vertical alignment requirements for a Type IA hoist. These block diagrams are not meant to show actual configurations and may be rearranged as needed to meet the specific application. These diagrams are only a few of many acceptable configurations.

HT-2.3 MECHANICAL REQUIREMENTS (TYPE IA)

(a) 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 hang-up.

(1) Motor stall torque shall be considered, as well as all other factors contributing to maximum loading of the equipment components.

(2) 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 hang-up, shall permit the hoisting machinery to be returned to service without need for repair or replacement of components. Should any device in the hoist drivetrain, such as a clutch or torque limiter, fail to hold the load, the emergency brake (or other secondary or redundant load path) shall engage (or remain engaged) and safely retain the load.

(b) Allowable stresses for hoisting machinery components during these events shall be limited to 75% of the yield strength.

(c) 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.

(d) Design calculations demonstrating the capability of the crane system to withstand severe overloads, including two-blocking and load hang-up, shall be submitted to the owner.

HT-2.3.1 Reeving

The reeving system shall be divided into two separate (redundant) 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. See Figures HT-2.3.1-1 through HT-2.3.1-3 for examples of Type IA reeving systems. These figures show three of many acceptable configurations.

(a) In each load path, multiple parts of rope in the reeving system shall be equalized.

(b) Each load path in the reeving system shall be balanced with the others.

HT-2.3.2 Hoooks and Load Blocks

HT-2.3.2.1 Hooks. Hooks shall be designed for twice the rated load [e.g., for a 5-ton maximum critical load (MCL) rating, the design load shall be 10 tons] or shall be of single-failure-proof design.

(a) If the hooks are the swiveling type, they shall be capable of rotating through 360 deg when supporting the rated load unless otherwise specified by the owner.

(b) Hook latches shall be provided unless the application makes use of the latch impractical. When required, a hook latch shall be provided to bridge the throat opening of the hook for the purpose of retaining slings, chains, etc., under slack conditions. Depending on the conditions of service, consideration shall be given to the use of hook latches constructed of corrosion-resistant materials.

(c) All hooks and latches shall comply with ASME B30.10.

Figure HT-2.2-1
Type IA Wire Rope Dual Hoist Drive Unit With Single Drum

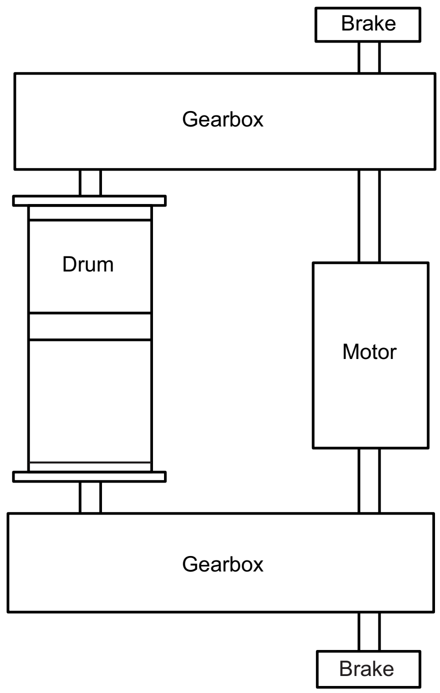


Figure HT-2.2-3
Type IA Wire Rope Dual Hoist Drive Unit With Dual Drum

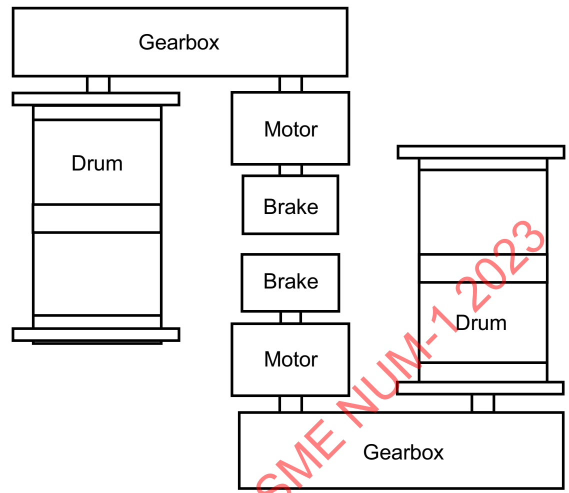


Figure HT-2.2-2
Type IA Wire Rope Single Hoist Drive Unit With Drum Brake

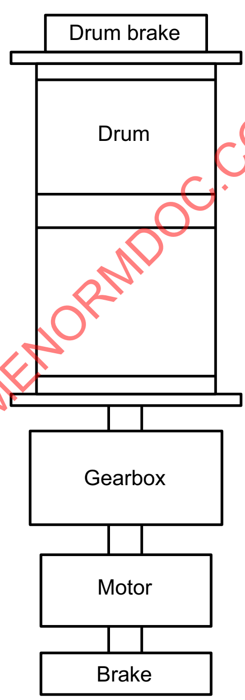
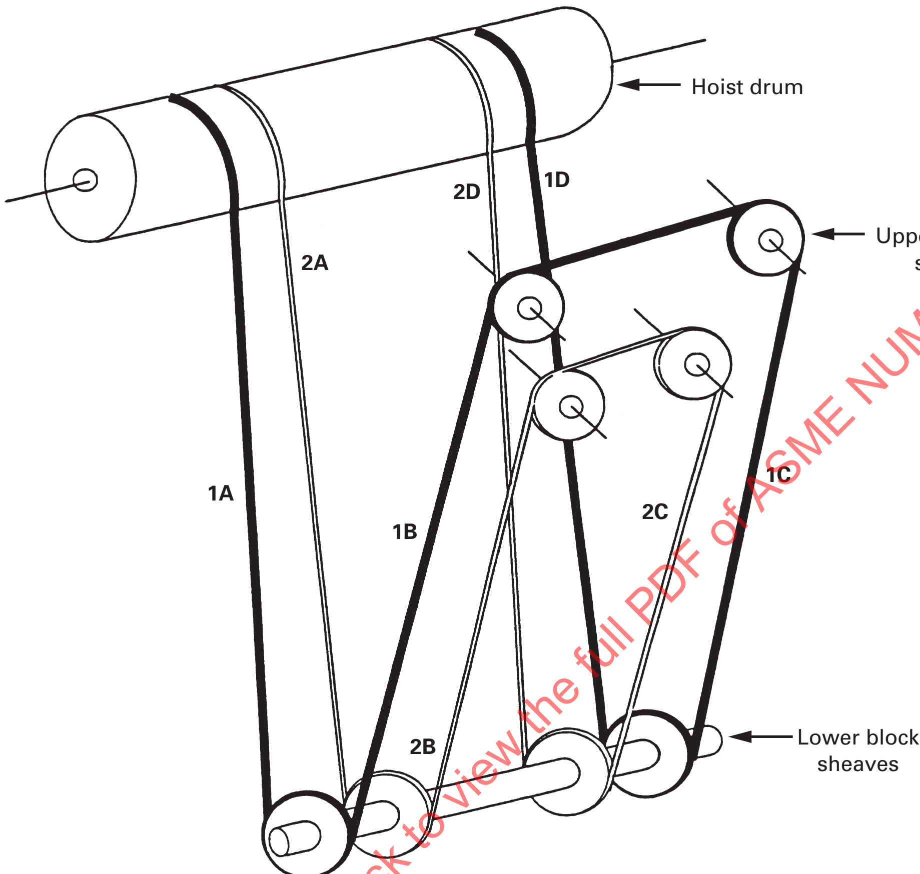
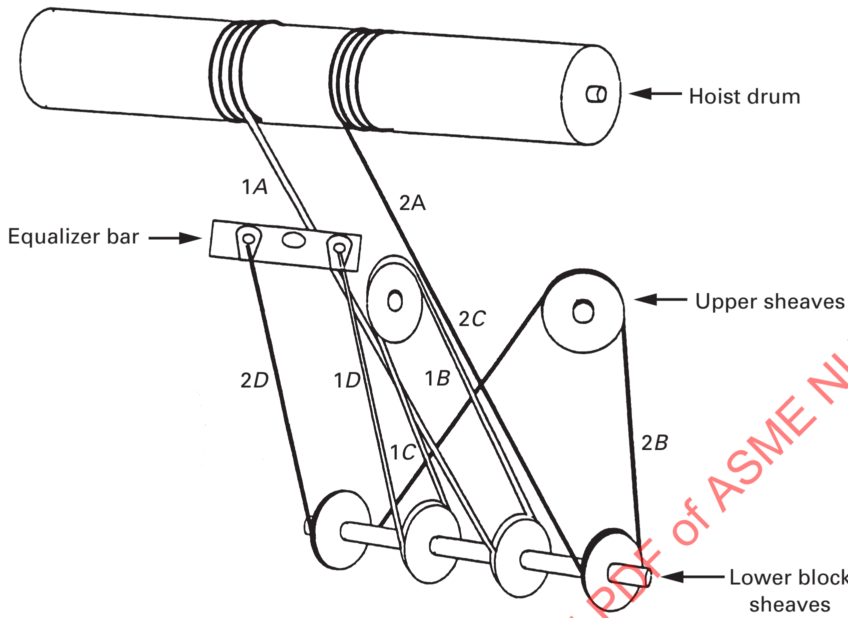


Figure HT-2.3.1-1
Type IA Redundant Reeving With Single Drum (With Upper Equalizer Sheaves)



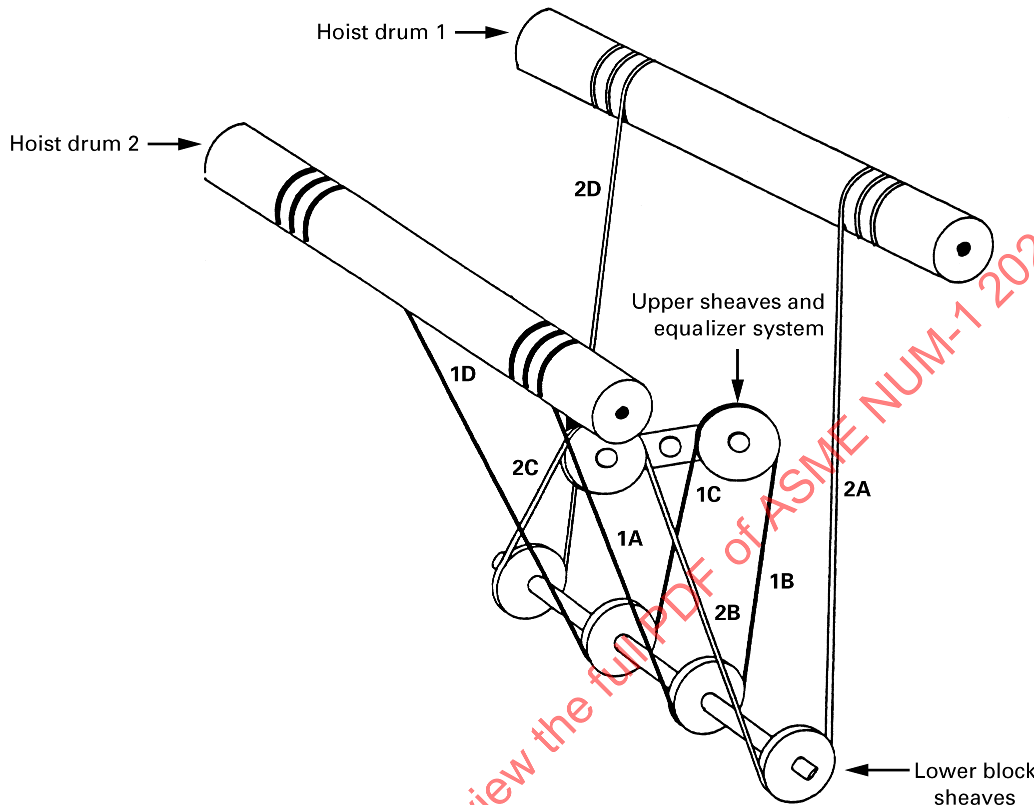
GENERAL NOTE: The relative position of the sheaves is extended and the angle of the view is distorted to clarify reeving paths. An equalizer system between the two ropes is required but is not shown for clarity.

Figure HT-2.3.1-2
Type IA Redundant Reeving With Single Drum (With Equalizer Bar)



GENERAL NOTE: The relative position of the sheaves is extended and the angle of the view is distorted to clarify reeving paths.

Figure HT-2.3.1-3
Type IA Redundant Reeving With Dual Drum



GENERAL NOTE: The relative position of the sheaves is extended and the angle of the view is distorted to clarify reeving paths.

HT-2.3.2.2 Load Blocks. Load blocks shall have double the normal design factors (e.g., for a 5-ton MCL rating, the design load shall be 10 tons) or shall be of a single-failure-proof design. Load blocks shall be of the guarded or enclosed type and shall guard against rope jamming under normal operating conditions.

HT-2.3.2.3 Upper Blocks. The upper block (or upper sheave nest) shall have double the normal design factors or shall be of single-failure-proof design.

HT-2.3.3 Wire Rope

(a) Type and Construction of Wire Rope. Wire rope shall be of a type and construction suitable for hoist service.

(b) Selection of Ropes. Hoisting ropes shall be selected based on the more stringent of the following requirements.

(1) 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 $12\frac{1}{2}$% of the manufacturer's published breaking strength on the total system or 25% on each of the dual systems.

(2) In the event of rope failure, the impact load in the transfer of the maximum critical load from one of the dual hoisting rope systems to the other shall not exceed 40% of the manufacturer's published breaking strength.

(3) The seismic load with all parts of rope intact shall not exceed 40% of the manufacturer's published breaking strength.

(4) The load resulting from the maximum possible overload of the hoisting machinery, including two-blocking and load hang-up, shall not exceed 40% of the manufacturer's published breaking strength.

(c) The rope ends shall be attached to the hoist in such a manner as to prevent disengagement throughout rated hook travel.

(d) End terminations shall be in accordance with the Wire Rope User's Manual and shall be equal to the required rope strength. Wire rope clips shall not be used as the primary end terminations.

(e) The rope fleet angle to the drum grooves shall be limited to $3\frac{1}{2}$ deg, except the last 3 ft of the maximum lift elevation, which shall be limited to 4 deg. See Figure HT-2.3.3-1 for fleet-angle measurement to the drum grooves.

Figure HT-2.3.3-1
Drum Fleet Angle

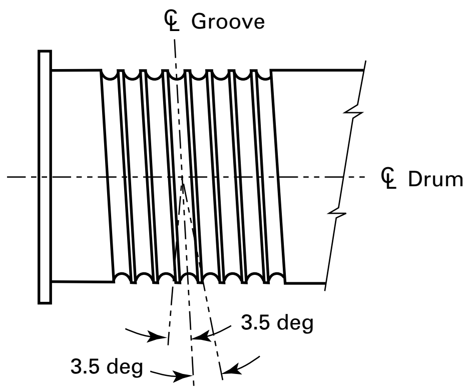
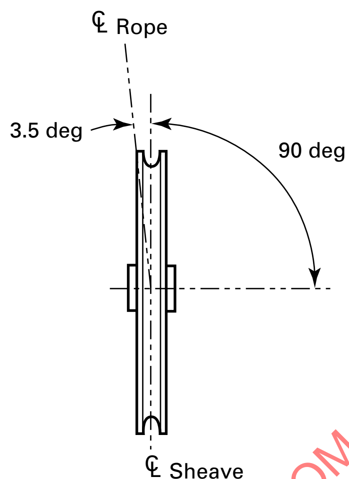


Figure HT-2.3.3-2
Sheave Fleet Angle



(f) Rope fleet angle for sheaves shall be limited to $3\frac{1}{2}$ deg, except the last 3 ft of maximum lift elevation, which shall be limited to $4\frac{1}{2}$ deg. See Figure HT-2.3.3-2 for fleet-angle measurement to the sheaves.

HT-2.3.4 Sheaves

(a) Sheave grooves shall be smooth and free from surface irregularities that could cause rope damage. The cross-sectional radius at the bottom of the groove should be such as to form a close-fitting saddle for the size of the rope used, and the sides of the groove should be tapered outwardly to facilitate entrance of the rope into the groove. Flanges shall be rounded and the rims shall run true about the axis of rotation.

(b) Sheaves shall be mounted and guarded to protect against the entrance of foreign objects, wire rope jamming, and wire rope displacement during normal operation.

(c) All running sheaves shall use antifriction bearings. All running sheave bearings, except permanently lubricated bearings, shall be equipped with means for lubrication.

(d) Equalizer sheaves shall be provided with bronze bushings, oil-impregnated bearings, antifriction bearings with grease fittings, or other means to ensure that the sheave bearing remains lubricated, ensuring its capability to provide the rotation required to equalize the reeving.

(e) Equalizer systems shall be able to withstand the dynamic forces from load transfer upon failure of one wire rope and shall not load the remaining intact reeving system more than 40% of the breaking strength of the wire rope.

(f) The pitch diameter of running sheaves shall not be less than that indicated in Table HT-2.3.4-1.

(g) The pitch diameter of nonrunning sheaves (equalizers) shall not be less than 12 times the rope diameter.

HT-2.3.5 Drums

(a) Provisions shall be made to retain the drum and the load in the event of drum shaft or bearing failure.

(b) Rope drums shall be grooved, and the grooves shall be smooth and free from surface irregularities that could cause rope damage. The cross-sectional radius at the bottom of the groove should form a close-fitting saddle for the size of the rope used. The top edge of the grooves shall be rounded to minimize rope damage and wear.

(c) Rope drums shall be flanged to guard against ropes sliding over the ends of the drum. Drums that are mounted in the hoist structure such that the rope cannot slip over the drum ends do not require flanges.

(d) All rope drums shall have only one layer of rope and the drum shall be designed to store the entire length of rope for the rated lift with the load block in its uppermost position.

(e) No less than two wraps of rope shall remain on each anchorage of the hoist drum when the hook is in its lowest position unless a lower limit device is provided, in which case no less than one wrap shall remain on each anchorage of the hoist drum.

(f) The minimum drum groove depth shall be 0.5 times the rope diameter.

(g) The minimum drum groove pitch is either 1.14 times the rope diameter or the rope diameter plus $\frac{1}{8}$ in., whichever is smaller.

(h) The rope drum pitch diameter shall not be less than that indicated in Table HT-2.3.5-1.

Table HT-2.3.4-1
Minimum Pitch Diameter of Running Sheaves

Hoist Duty Class	Minimum Pitch Diameter of Running Sheave 6X37 Class Rope	6X19 Class Rope
H1 and H2	16*d*	20*d*
H3	18*d*	24*d*
H4	20*d*	24*d*
H5	24*d*	30*d*

Legend:
d = rope diameter

Table HT-2.3.5-1
Minimum Pitch Diameter of Drums

Hoist Duty Class	Minimum Pitch Diameter of Drums 6X37 Class Rope	6X19 Class Rope
H1 and H2	16*d*	20*d*
H3	18*d*	24*d*
H4	20*d*	24*d*
H5	24*d*	30*d*

Legend:
d = rope diameter

Table HT-2.3.6.1-1
Bearing Life Expectancy

Hoist Duty Class	Minimum Bearing Life Expectancy, hr
H1	1,250
H2	2,500
H3	5,000
H4	10,000
H5	20,000

HT-2.3.6 Bearings, Rotating Shafts, and Keys

HT-2.3.6.1 Bearings

(a) Shaft bushings or bearings shall be enclosed against entry of dirt, dust, and other foreign material.

(b) All bearings and bushings shall be provided with means of lubrication.

(c) Hoist bearings shall be selected to give a minimum B10 life expectancy based on full rated speed from Table HT-2.3.6.1-1.

(d) Bearing loads, for life computation purposes, shall be determined using a mean effective load factor of 0.65.

HT-2.3.6.2 Rotating Shafts. Rotating shafts shall be supported by antifriction, lubricated, or self-lubricated bearings or bushings. All sliding surfaces shall be lubricated.

HT-2.3.6.3 Hoist Keys. Keys used in hoist drives shall only be of a parallel, square, or rectangular shape, not precluding the use of a splined shaft for power transmission.

HT-2.3.7 Hoist Gearing

(a) Gearing and associated shafts and couplings or other connection means shall be redundant (i.e., provide two separate load paths from the hoist brakes to the wire rope drum), with each independent gear train rated at full hoisting horsepower. As an alternative, a single hoist gear train may be provided in conjunction with two holding brakes, one of which shall act directly on the wire rope drum and set automatically upon failure or overspeed of the hoist drivetrain.

(b) Gears shall be constructed of steel or other material of adequate strength and durability to meet the requirements for the intended class of service. For this Standard, the strength and durability shall be based on the torque required to lift the rated load.

(c) Means shall be provided to ensure adequate and proper lubrication on all gearing.

(d) All gearing not enclosed in gear cases shall be guarded with provision for lubrication and inspection.

(e) Due consideration shall be given to the maximum brake torque that can be applied to the drive.

(f) The horsepower rating for all spur, helical, and herringbone gearing shall be based on ANSI/AGMA 2001-D04 and manufactured to AGMA quality class 6 or better. For this Standard, the power equations are as follows:

(1) *Allowable Strength Horsepower*

$$P_{at} = \left(\frac{n_p d}{126{,}000K_v}\right)\left(\frac{Fs_{at}J}{K_m P_d S_{fs} K_B}\right)$$

(2) *Allowable Durability Horsepower*

$$P_{ac} = \left(\frac{n_p F I}{126{,}000K_v K_m S_{fd}}\right)\left(\frac{s_{ac} d C_H}{C_p}\right)^2$$

where

C_d = machinery service factor (see Table HT-2.3.7-1)
C_h = hardness factor (durability)
C_p = elastic coefficient
d = pitch diameter of pinion, in.
F = net face width of the narrowest of the mating gears, in.
I = geometry factor (durability)
J = geometry factor (strength)
K_B = rim thickness factor
K_m = load distribution factor
K_v = dynamic factor
K_w = mean effective load factor = 0.667
n_p = pinion speed, rpm
P_{ac} = allowable durability, hp
P_{at} = allowable strength, hp

P_d = transverse diametral pitch, 1/in.
s_{ac} = allowable contact stress number (durability)
s_{at} = allowable bending stress for material (strength), psi
S_{fd} = hoist duty class factor (durability)
= $C_d K_w$
S_{fs} = hoist duty class factor (strength) (see Table HT-2.3.7-2)

The values of I, J, C_h, C_p, K_B, K_m, K_v, S_{ac}, and S_{at} can be determined from the tables and curves in the appropriate AGMA specification; S_{fs} is in Table HT-2.3.7-2; and the remaining values are physical characteristics pertaining to the gears for their operational characteristics.

(g) When worm gearing is called for, it shall be rated with appropriate service factors.

HT-2.3.8 Hoist Brakes

(a) The braking system shall consist of at least two holding brakes and a control braking means and shall perform the following functions:

(1) stop hook motion and hold the load when the controls are released

(2) limit the speed of the load during lowering to a maximum speed of 120% of rated lowering speed for the rated load

(3) stop and hold the load hook in the event of a complete power failure

(b) Each hoist 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 motion within a distance that ensures damage to the load and facility does not occur. A maximum lowering distance of 3 in. is recommended. Under normal operating conditions, the brakes shall apply automatically upon power removal. The application of the second (and any other additional) brake shall be delayed to minimize shock to the hoist drivetrain.

(c) The braking system shall have thermal capacity for the frequency of operation required by the hoist duty service classification.

(d) The hoist holding brakes shall have provision for adjustment to compensate for lining wear.

(e) The Type IA hoist 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 them acts directly on the wire rope drum shell or a flange or disk 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 shall 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 the brake shall 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 shall be capable thermally and in all respects of lowering the 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 shall remain effectively connected to the hoist drivetrain after failure of the other brake or any component of the hoist machinery. The design of hoist brakes and braking systems shall enable recovery from an inoperable brake with a rated load on the hoist. The recovery shall be accomplished by repair of the brake in place, by replacement of the brake in place, or by an alternative recovery means acceptable to the purchaser.

Table HT-2.3.7-1
Machinery Service Factor, C_d

Hoist Duty Class	C_d
H1	0.64
H2	0.72
H3	0.80
H4	0.90
H5	1.00

Table HT-2.3.7-2
Hoist Duty Class Factor (Strength), S_{fs}

Hoist Duty Class	S_{fs}
H1	0.75
H2	0.85
H3	0.90
H4	0.95
H5	1.00

HT-2.4 ELECTRICAL REQUIREMENTS (TYPE IA)

HT-2.4.1 General

All electrical equipment furnished shall conform to the applicable sections of the latest issue of NFPA 70. The owner shall specify the voltage, frequency, and phase of the power supply. The supply voltage shall be maintained within ±10% of the rated motor voltage of the hoist when the motor is operating at rated load.

HT-2.4.2 Controllers

HT-2.4.2.1 Types of Control. The type of control supplied for a hoist shall result in operation complying with the performance as defined in Section GR-3.

(a) Common Control Systems. Common control systems may be one of the following:

(1) single-speed alternating current (AC) magnetic reversing, which uses an AC squirrel-cage induction motor.

(2) two-speed AC magnetic reversing, which uses a dual-wound AC squirrel-cage induction motor. Speed ratios under any load are normally 3:1 but may also be furnished in other ratios, such as 2:1 or 4:1.

(3) variable-speed AC magnetic reversing, which is a type of constant potential AC control that uses resistance in the secondary of an AC-wound rotor induction motor. Three to five speed steps are normally provided, with the speed at each step varying depending on the load.

(4) AC variable-frequency control, which uses an AC squirrel-cage induction motor and provides either stepped or stepless speed control by varying the motor frequency (see para. HT-2.4.2.2).

(b) Other Control Systems. Other control systems, such as adjustable-voltage direct-current (DC) and adjustable-voltage AC, may be required depending on the specific application or owner specifications.

HT-2.4.2.2 Variable-Frequency Drive Hoist Controls. The general requirements for variable-frequency drive (VFD) hoist controls are as follows:

(a) Control shall consist of a variable-frequency drive (VFD) with a full load ampere (FLA) rating equal to or greater than the FLAs of the corresponding motor or motors.

(b) Control shall include, as a minimum, the following protective features:

(1) output phase loss

(2) undervoltage

(3) overvoltage

(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 power supply and electronic equipment shall be protected from detrimental effects due to harmonic distortion, electromagnetic interference, or radio frequency interference produced by inverters.

(f) For VFDs used in hoisting applications that do not use a mechanical load brake, speed feedback shall be incorporated.

HT-2.4.2.3 Contactors. Each magnetic control shall have contactors sized for the specified service. Reversing contactors shall be interlocked to guard against line-to-line faults.

HT-2.4.3 Motors

HT-2.4.3.1 General

(a) AC Motors

(1) Definite-Purpose Inverter-Fed Motors. AC squirrel-cage motors applied to 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, parts 18.501 through 18.520.

(3) Other AC Motors. All other AC motors not already described shall conform to NEMA MG-1.

(b) Direct-Current Motors. DC motors shall be in accordance with either NEMA MG-1 or AISE Standard No. 1.

(c) Enclosures and Time Ratings. All AC or DC motors shall have enclosures and time ratings as required for the duty and environmental conditions.

(d) Operation Characteristics. Motors shall be reversible, with torque characteristics suitable for hoist or trolley service, and capable of operation at rated loads and speeds in accordance with the class of service specified.

(e) Temperature Rise. The temperature rise of motors shall be in accordance with the latest NEMA standards for the class of insulation and enclosure used. The hoist manufacturer will assume 104°F ambient temperature unless otherwise specified by the owner.

(f) Phase Protection. Hoist motors shall have phase-loss and phase-reversal protection.

HT-2.4.3.2 Motor Voltage

(a) All AC motors at rated frequency and all DC motors shall be capable of operation within ±10% of rated motor voltage, but not necessarily at rated voltage performance.

(b) Standard rated motor voltage shall be in accordance with Table HT-2.4.3.2-1.

(c) For nominal system voltages other than shown in Table HT-2.4.3.2-1, the rated motor voltage should not be less than 95% nor more than 100% of the nominal system voltage.

Table HT-2.4.3.2-1
Standard Rated Motor Voltages

Power Supply	Nominal System, V	Rated Motor, V	Permissible Motor Operating Range, V
AC, single phase 60 Hz	120	115	104 to 126
	240	230	207 to 253
AC, polyphase 60 Hz	208	200	180 to 220
	240	230	207 to 253
	480	460	414 to 506
	600	575	518 to 632
AC, polyphase 50 Hz	208	200	180 to 220
	230	220	198 to 242
	400	380	342 to 418
DC	125	115	104 to 126
	125	120	108 to 132
	250	230	207 to 253
	250	240	216 to 264

HT-2.4.3.3 Motor Time Rating. The motor time rating shall result in operation that complies with the specified performance as defined in Section GR-3, taking into consideration any supplemental requirements specified by the owner.

(a) Minimum Time Ratings. Single-speed, two-speed, variable-speed, and inverter-fed motors shall be rated on no less than a 30 min basis under rated load, with the temperature rise in accordance with the class of insulation and enclosure used. The low-speed winding of a two-speed motor may be rated less than 30 min and the lower stepping speeds of a variable-speed control will have a substantially lower operating time.

(b) Long-Lift Hoists. The use of 60 min or continuous-duty motors shall be considered for use with long-lift hoists.

(c) Adjustments for Unusual Conditions. Under unusual conditions, such as abnormal inching or jogging requirements, cyclical hoist movements, altitudes more than 3,300 ft above sea level, or abnormal ambient temperatures, the motor time rating shall be increased as appropriate.

HT-2.4.3.4 Hoist Motor Size Selection. Electric motors shall have a required rated motor horsepower not less than that given by the following equation:

$$HP_{required} = HP_{mechanical} \times K_c$$

where

$$HP_{mechanical} = \frac{WV}{33{,}000E}$$

and

E = mechanical efficiency between the load and the motor, expressed in decimal form
= $E_g^{\ n} \times E_s^{\ m}$

E_g = efficiency per gear reduction
= 0.97 for spur, herringbone, and helical gearing supported on antifriction bearings
= 0.93 for spur, herringbone, and helical gearing supported on sleeve bearings

NOTE: For the E_g value for worm gearing, consult the gear and hoist manufacturer.

E_s = rope system efficiency per rotating sheave
= 0.99 for rotating sheaves supported on antifriction bearings
= 0.98 for rotating sheaves supported on sleeve bearings

K_c = control factor, which is a correction value that accounts for the effects the control has on motor torque and speed
= 1 for the majority of controls, such as AC wound rotor magnetic, inverter, or static systems where there are no secondary permanent slip resistors; systems for squirrel-cage motors; and constant potential magnetic systems with DC power supplies

m = number of rotating sheaves between the drum and equalizer passed over by each part of moving rope attached to the drum

n = number of gear reductions

V = specified speed when lifting weight W, ft/min

W = total weight to be lifted (rated load plus the weight of the load block), lb

For AC wound rotor systems, magnetic or static control with secondary permanent slip resistors, K_c shall be as follows:

$$K_c = \frac{\text{motor-rated full load, rpm}}{\text{motor-operating rpm, at rated torque with permanent slip resistors, when hoisting}}$$

K_c values for power supplies rectified on the hoist shall be determined by consulting with the motor and control manufacturers.

HT-2.4.4 Limit Devices

HT-2.4.4.1 General. A limit device is defined as a switch or sensing system that provides control functions on a crane. Paragraphs HT-2.4.4.2 through HT-2.4.4.7 include 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.

HT-2.4.4.2 Type IA Hoist Safety-Critical Limit Devices

(a) Safety Detection Requirements. The hoist shall have means to detect the following conditions:

(1) final high hoist overtravel
(2) overload limit
(3) hoist drum wire rope mis-spooling
(4) hoist overspeed
(5) equalizer travel error

Additional requirements for these safety detection systems are provided in paras. HT-2.4.4.3 through HT-2.4.4.7.

(b) 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 determines and corrects the cause of device activation.

(c) 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.

EXCEPTION: Safety-critical limit devices may be part of the limiting means or control devices if there is independent monitoring of the means or device.

HT-2.4.4.3 Overtravel Protection. Hoists shall have the following limit features:

(a) First High Hoist Overtravel 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 of the hoist brakes. The operator may lower or back out of this tripped switch without further assistance.

(b) Final Hoist High Overtravel Limit. In addition to the first upper limit switch, a final power circuit hoisting limit switch shall directly remove power from the hoist motor and set the hoist brakes.

(c) If the hoist is designed to withstand two-blocking, only the first high hoist overtravel limit switch is required. In this case, the ropes shall not be cut or crushed nor the hoist damaged in the event of load block overtravel.

(d) Low Hoist Overtravel Limit. The hoist 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.

HT-2.4.4.4 Overload-Limiting Devices

(a) An overload-limiting device, when furnished, shall be designed to permit operation of the hoist within its rated load and to limit the amount of overload that can be lifted by a properly maintained hoist under normal operating conditions.

(b) The overload-limiting device may allow the lifting of an overload but shall be designed to prevent the lifting of an overload that could cause damage to the hoist. This does not imply that any overload is to be intentionally applied to the hoist.

HT-2.4.4.5 Hoist Drum Wire Rope Spooling Monitor. Hoists shall include a wire rope spooling device to detect improper threading of the hoist rope in the hoist drum grooves. Actuation of this device shall result in removal of power from the hoist motor and the setting of hoist holding brakes. Actuation of this limit device shall prevent further hoisting. A mechanical rope guide that encompasses the circumference of the drum and provides spooling of the wire rope onto the drum may be used in lieu of a spooling device.

HT-2.4.4.6 Hoist Overspeed Limits

(a) Electrically operated hoists that handle critical loads shall include an overspeed limit device (switch or sensing system). When handling a critical load, hook speeds greater than 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 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 for wire rope hoists shall be located so that it monitors drum rotation irrespective of a single failure in the drivetrain.

(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.

HT-2.4.4.7 Equalizer Travel Error Indication Device. A sensing and signaling means shall be provided to automatically shut down the hoist and provide an indication to the operator if displacement between the separate reeving systems exceeds design operating limits.

HT-2.4.5 Control Enclosures

Control enclosures, unless otherwise specified by the owner, shall be in accordance with NEMA ICS 6. Enclosure types, as defined by NEMA, include but are not limited to the following:

(a) NEMA Type 1: general purpose for indoor applications
(b) NEMA Type 3: watertight, dust-tight, and sleet (ice) resistant; outdoor
(c) NEMA Type 3R: rainproof and sleet resistant; outdoor
(d) NEMA Type 4: watertight and dust-tight; indoor and outdoor
(e) NEMA Type 4X: watertight, dust-tight, and corrosion resistant; indoor and outdoor
(f) NEMA Type 7: Class I, Groups A, B, C, and D; indoor hazardous locations (explosive atmosphere)
(g) NEMA Type 9: Class II, Groups E, F, and G; indoor hazardous locations (explosive atmosphere)
(h) NEMA Type 12: industrial use; dust-tight and drip-tight; indoor

HT-2.4.6 Additional Electric Equipment

Each Type IA electric-operated wire rope hoist shall have the following:
(a) phase loss protection
(b) phase reversal protection
(c) mainline magnetic contactor operated by a power off or emergency stop button
(d) motor thermal detectors

HT-2.4.7 Resistors

Resistors, when furnished, shall have sufficient thermal capacity for the specified class of service. Enclosures for resistors shall provide means for heat dissipation and shall be installed to minimize the accumulation of combustible matter. Provision shall be made to contain broken resistor parts or molten metal.

HT-2.4.8 Current Conductor Systems

Current conductor systems are not normally supplied with electric wire rope hoists. When required, they shall be specified by the owner. Standard systems include the following:
(a) flexible cable
(b) coiled cord
(c) festooned cable arrangement
(d) cable reel
(e) rigid conductor
(f) energy chain

HT-2.5 PNEUMATIC REQUIREMENTS (TYPE IA)

HT-2.5.1 Air Supply

Hoists shall operate on an air supply that is essentially clean and dry with pressure at 90 psi, although air systems at 105 psi may be used if accepted by both the owner and hoist manufacturer. Unless specified otherwise, the maximum moisture content of the air shall be 0.002 lb of water per pound of dry air at 60°F and 90 psia, with the maximum solid particulate contamination limited to 25 μ. The owner's main air supply shall be sufficient to accommodate the total air consumption of all air motors, with this consumption rate (in cubic feet per minute) provided by the manufacturer. The owner's main air supply shall include a building-mounted shutoff valve and an air regulator valve in the area of the hoist or crane. Additionally, the owner shall provide a relief valve system to prevent excessive air pressure, such as could be developed by the owner's air compressor system, from damaging the hoist.

HT-2.5.2 Air Motors

The air motor shall be an air-driven piston or rotary-vane type and shall be provided with an air inlet connection fitted for the use of air hose assemblies. Also, the air motor shall be provided with an oiler and air filter between the motor and the air inlet connection. The motor shall have adequate capacity to lift 125% of the rated load. The air motor shall have a required rated motor horsepower not less than that given by the following equation:

$$HP_{required} = \frac{WV}{33{,}000E}$$

where E, V, and W are as defined in para. HT-2.4.3.4.

HT-2.5.3 Additional Air Hoist Equipment

Air hoist motors shall be furnished with the necessary directional valves, a dump valve operated by a power off or emergency stop button, and a hoist-mounted regulator and pressure gauge to confirm the pressure at the hoist. The air motor exhausts shall include as necessary an exhaust filter and muffler. Mufflers are required for indoor service and shall be such that the motor sound level for each hoist shall be 80 db or less 3 ft from the muffler unless specified otherwise by the owner.

HT-2.5.4 Limiting Devices for Air-Operated Hoists

Limiting devices for a Type IA air-operated wire rope hoist shall be the same as those for a Type IA electric wire rope hoist, with the requirement for these devices listed under para. HT-2.4.4. However, for an air-operated hoist, some of the limiting devices may need to be electrically operated, in which case the devices would be categorized as electric-over-air-operated devices.

HT-2.6 OPERATOR CONTROL STATION (TYPE IA)

The hoist's operator control station type and location, with inclusion of any other motions (i.e., trolley, bridge, and jib), shall be specified by the owner. Examples of various operator control stations are as follows:

(a) floor operated, where the equipment motion is controlled by an operator on the floor or on an independent platform through use of a suspended pendant station

(b) remote operated, where the equipment motion is controlled by an operator through use of controllers contained in a remote operating station not attached to the hoist, trolley, or crane, or by means of a radio transmitter

(c) cab operated, where the equipment motion is controlled by an operator through use of controllers located in an enclosed or open cab attached to the hoist, trolley, or crane

(d) pulpit operated, where the equipment motion is controlled by an operator though use of controllers located in a fixed operator station not attached to the hoist, trolley, or crane

(e) pull-cord operated, where the equipment motion is controlled by an operator though use of suspended self-centering nonconducting pull cords with handles

All operator control stations shall meet the criteria addressed in ASME B30.16 and ASME B30.17. Arrangement of the control station's controllers or master switches are provided under para. CM-4.1.1.5.

HT-2.7 SEISMIC REQUIREMENTS (TYPE IA)

The Type IA hoist unit, being of a compact design and suspended from a crane or monorail, shall be considered a lumped mass for input into the crane or monorail seismic analysis as addressed in Section CM-2. However, the hoist unit itself shall be analyzed to ensure that the hoist unit and the trolley to which it is connected remain in place during and after a seismic event. As required, seismic restraints shall be provided for this purpose. Allowable stresses of mechanical fasteners of hoist and trolley connections under seismic loads shall not exceed 90% of the yield strength of the fastener.

HT-2.8 HOIST MARKING (TYPE IA)

(a) For Type IA hoists, the MCL shall be marked on the hoist or the load block. The abbreviation "MCL" shall be part of the marking.

(b) For Type IA hoists that lift loads in excess of the MCL, the design rated load shall also be marked on either the hoist or the load block. The abbreviation "DRL" shall be part of this marking.

HT-2.9 INSPECTIONS AND TESTS FOR POWERED WIRE ROPE HOISTS (TYPE IA)

HT-2.9.1 Hoist Component Inspections or Tests

The required component inspections and tests for a Type IA powered wire rope hoist shall be as listed in Table HT-2.9.1-1. The criteria for these inspections and tests are as follows:

(a) Material test reports shall include both chemical analysis and physical properties on the actual component materials of those items listed on Table HT-2.9.1-1.

(b) Surface magnetic particle testing (MT) or penetrant testing (PT) shall be performed on on each hoist hook and hook nut or any attachment devices after performing the hook proof load test described in (j). Other components listed in Table HT-2.9.1-1 that require surface MT or PT shall require these tests on the finished component part. The MT and PT procedures and acceptance criteria shall be in accordance with Section HT-7.

(c) Impact testing, either Charpy-V or drop weight, shall be performed on the actual component material of those items listed on Table HT-2.9.1-1 unless the component material has a thickness of $^5/_8$ in. or less. The Charpy-V or drop-weight testing criteria shall be in accordance with Section HT-7.

(d) A breaking strength test for the hoist wire rope shall be performed on the actual hoist rope, or on the actual rope lot used on the hoist, and shall require the wire rope to be pulled to the breaking load. Additionally, where rope end fittings are used in direct tension in the load path, at least one identical fitting shall be tested with the rope sample being pulled to failure, confirming that failure occurs in the rope and not at the fitting.

(e) The welds as listed on Table HT-2.9.1-1 shall require NDE, consisting of visual examination and either MT or PT, with procedures and acceptance criteria in accordance with Section HT-7. Such welds shall also require weld filler metals to have a certificate of conformance for the specific production batch that documents operating parameters, mechanical properties, and chemical composition. Additionally, all such welds shall be performed by welders who have been AWS certified for the specific welding process that was used, with these certificates provided as part of the documentation package.

(f) A certificate of conformance shall be furnished specifically for the hoist wire rope, separate from any other certificates of conformance. This wire rope certificate, which may be provided as part of the documentation on the wire rope breaking strength test, shall specify the safe working load limit and the breaking load. This certificate shall also identify the wire rope's diameter, rope lay, manufacturer's designation of the rope grade, and all construction details of the rope strands, individual wires, and rope core. Any limitations or restrictions on the use of the rope with regard to sheave diameters or fleet angles shall be identified in this certificate.

(g) A certificate of conformance shall be furnished specifically for any wire rope end fittings (such as eyes and sockets), separate from any other certificates of conformance. This wire rope end fitting certificate, which may be provided as part of the documentation on the wire rope end fitting proof test, shall specify

the type of end fitting, the terminations efficiency, and any limitations on this efficiency due to the rope's construction or grade.

(h) A certificate of conformance shall be furnished for each different hoist sheave by the sheave manufacturer, separate from any other certificates of conformance. This sheave certificate shall identify the sheave manufacturer, sheave part or stock number, sheave pitch diameter, wire rope size to be accommodated, groove depth, capacity rating, and sheave material.

(i) The components listed on Table HT-2.9.1-1 shall require UT of the finished item, with procedures and acceptance criteria in accordance with Section HT-7.

(j) Hooks shall be proof load tested in accordance with the criteria of ASME B30.10, with throat opening dimensions taken before and after this test. This test shall also include the proof testing of the hook nut or hook attachment device.

(k) The proof load test of any wire rope end fitting shall be performed at 40% of the rope's published breaking strength.

(l) Documentation on the above listed component inspections, tests, and certificates of conformance shall be furnished as part of the seller's documentation package to qualify the hoist as NUM Type IA.

HT-2.9.2 Hoist Shop Performance and Shop Load Tests

Each Type IA power-operated wire rope hoist shall require the shop performance and load tests described in paras. HT-2.9.2.1 through HT-2.9.2.8.

HT-2.9.2.1 No-Load Performance Test. A no-load shop performance test shall be conducted through all speeds from the operator control station. If the actual control station is not available, a duplicate control station may be used for test purposes. The maximum no-load speed shall be documented. This performance test shall also verify the operation of all upper and lower limit devices, with the initial limit device tests being at the lower hoist speeds.

HT-2.9.2.2 Two-Block Test. With all high hoist overtravel limit switches bypassed, the hoist shall be two-blocked to demonstrate that the equipment is capable of being two-blocked without damage, and specifically confirming that the wire rope is not cut or damaged. It is recommended that the two-block test be conducted at the highest hoisting speed produced by normal operations. However, the owner and supplier may agree on alternate speeds for this test or alternative methods for demonstrating the capability of the equipment to withstand two-blocking.

HT-2.9.2.3 Rated Load Test (125% of MCL). A hoist rated load test of at least 125% of the MCL rating shall be performed.

HT-2.9.2.4 Overload Limit Test. A load shall be applied above the hoist's MCL rating to confirm and document the overload setting. Air-operated hoists that lower the air pressure to set an inherent overload-limiting capability of the hoist shall require documentation of the no-load speed at this lower air pressure to supplement the original no-load performance test.

HT-2.9.2.5 Performance Test (100% of MCL). A hoist performance test at 100% of the MCL rating shall be performed, documenting the maximum hoist raising and lowering speeds for the MCL rating.

HT-2.9.2.6 Redundant Holding Brake Test. The redundant hoist holding brakes shall be verified to confirm that each braking system can independently hold the 100% MCL rating.

HT-2.9.2.7 Loss of Power Test. While raising and lowering 100% of the MCL rating, the main power, electric or air, shall be interrupted to confirm that the holding-brake systems engage to hold the MCL. Manually operated load-lowering devices, if supplied, shall be tested.

HT-2.9.2.8 Shop Test Documentation. Documentation on the above-listed shop tests shall be furnished as part of the seller's documentation package to qualify the hoist as NUM Type IA.

HT-2.9.3 Site Load Tests

Hoists suspended from a crane or monorail shall be site load tested as stated under para. CM-7.1.7.

Table HT-2.9.1-1
Required Hoist Component Inspections or Tests (Type IA Powered Wire Rope Hoists)

	Material Test Report [Note (1)]	Certificate of Conformance [Note (2)]	NDE of Welds [Note (3)]	UT [Note (4)]	Surface MT or PT [Note (5)]	Impact Test [Note (6)]	Proof Load Test [Note (7)]	Breaking Strength Test [Note (8)]	Weld Filler Material Certificate of Conformance [Note (3)]	Welder Certificates [Note (3)]
Hook	X	...	...	X	X	...	X	...	...	...
Hook nut or attachment device	X	...	...	X	X	...	X	...	...	...
Hook trunnion cross head and load block structure (cast or forged)	X	...	...	X	X	...	...	...	...	...
Hook trunnion cross head and load block structure (rolled)	X	...	...	...	...	X	...	...	...	...
Load block structure welds	...	...	X	...	...	...	...	...	X	X
Load block sheave pin	X	...	...	X	X	...	...	...	...	...
Wire rope	...	X	...	...	...	...	...	X	...	...
Wire rope end fittings (such as eyes and sockets)	...	X	...	...	...	...	X	X	...	...
Hoist drum	X	...	...	...	...	...	...	...	...	...
Hoist drum shell and hub welds	...	...	X	...	...	...	...	...	X	X
Hoist drum shaft	X	...	...	X	X	...	...	...	...	...
Upper block sheave pin	X	...	...	X	X	...	...	...	...	...
Upper block load structure (cast or forged)	X	...	...	X	X	...	...	...	...	...
Upper block load structure (rolled)	X	...	...	...	...	X	...	...	...	...
Upper block structural welds	...	...	X	...	...	...	...	...	X	X
Sheaves	...	X	...	...	...	...	...	...	...	...
Gears, pinions, and shafts	X	...	...	X	X	...	...	...	...	...

NOTES:
(1) Material test reports shall be per para. HT-2.9.1(a).
(2) Certificate of conformance criteria are to be per para. HT-2.9.1(f) for hooks, para. HT-2.9.1(g) for hook nuts, and para. HT-2.9.1(h) for sheaves.
(3) Specific criteria for NDE of welds, criteria for weld filler material certificates of conformance, and welder certificates are to be per para. HT-2.9.1(e).
(4) Specific criteria for the UT of components are to be per para. HT-2.9.1(i).
(5) Specific criteria for surface MT or PT are to be per para. HT-2.9.1(b).
(6) Specific criteria for impact tests are to be per para. HT-2.9.1(c).
(7) Proof load test criteria are to be per para. HT-2.9.1(j) for hooks and hook nut or attachment device, and per para. HT-2.9.1(k) for wire rope end fittings.
(8) Specific criteria for breaking strength test of wire rope and rope end fittings are to be per para. HT-2.9.1(d).

Section HT-3
Powered Wire Rope Hoists (Type IB)

HT-3.1 GENERAL

This Section provides the requirements for powered (electric- or air-operated) Type IB hoists for enhanced safety vertical lifting of freely suspended unguided loads using wire rope as a lifting medium.

A Type IB powered wire rope hoist shall be a standard hoist meeting the criteria of ASME B30.16, and either ASME HST-4 for electric operation or ASME HST-6 for pneumatic (air) operation, with its MCL rating being no more than one-half of its original design capacity per these standards. However, to qualify for Type IB classification, the hoist shall also meet the additional design, inspection, testing, and documentation requirements of this Section.

EXAMPLE: For a hoist to qualify as a 2-ton MCL-rated Type IB hoist, its original design rating would have to be 4 ton or greater, but if it did not meet the additional design, inspection, testing, and documentation requirements of this Section, it would not be qualified as a Type IB hoist.

HT-3.2 EQUIPMENT CONFIGURATIONS (TYPE IB)

(a) The hoisting machinery from the motor to the drum is not designed to tolerate a single component failure. Instead, increased design factors are applied to reduce the probability of a component failure such that it is no longer considered to be a credible failure.

(b) The equipment configurations are similar to those of a standard wire rope hoist, but a Type IB hoist shall have a secondary means of holding the load or retarding the lowering speed of the load to an evaluated facility-acceptable limit.

(c) Figures HT-3.2-1 and HT-3.2-2 show examples of Type IB wire rope hoist equipment configurations. These block diagrams show conceptual layouts only. The blocks in the diagrams may be rearranged as needed to meet the specific application. These diagrams depict only a few of many acceptable configurations.

HT-3.3 MECHANICAL REQUIREMENTS (TYPE IB)

All load suspension parts shall be designed so that the static stress calculated for the MCL rating shall not exceed 10% of the minimum tensile strength.

NOTE: Limiting the static stress based on the MCL rating is equivalent to designing all load suspension parts to a static stress based on the hoist's design rating to not exceed 20% of the minimum tensile strength.

HT-3.3.1 Reeving

Hoist reeving may be either single or double and may be one part or multiple parts. Since such standard reeving systems are not single failure proof and cannot safely accommodate a two-blocked condition, a limiting device is required to prevent two-blocking. See para. HT-3.3.7.

(a) On single-reeved hoists, one end of the rope is attached to the drum. 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 Figure HT-3.3.1-1.

(b) On double-reeved hoists, both ends of the rope are attached to the drum. The drum is grooved with left-hand and right-hand grooves beginning at both ends of the drum, with the grooves threaded 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 of the drum. Refer to Figure HT-3.3.1-2.

HT-3.3.2 Hooks

Hooks shall have a design factor of at least 10:1 on the hoist's MCL rating based upon the average ultimate load or force at which the hook fails or no longer supports the load. Hooks shall be proof load tested based upon the hook's original working load limit before being derated for use on an MCL hoist, as specified under para. HT-3.8.1.

HT-3.3.3 Wire Rope

Wire ropes shall have a multi-strand construction for a powered hoisting application. Ropes shall meet the criteria of ASME B30.16 except that they shall have a design factor of at least 10:1 on the hoist's MCL rating based upon the rope's minimum breaking force. Wire ropes shall be pull-tested to their breaking load as required under para. HT-3.8.1.