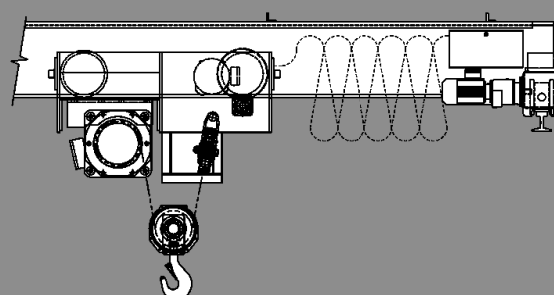
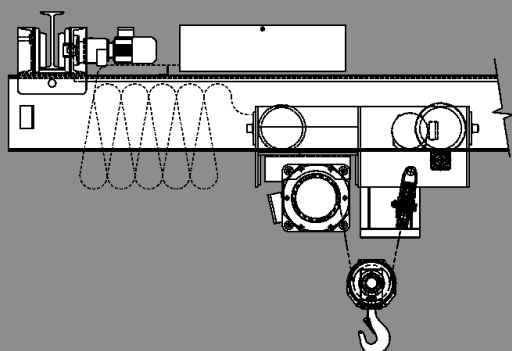


Specifications for Top Running & Under Running Single Girder Electric Traveling Cranes Utilizing Under Running Trolley Hoist

Prepared by
The Crane Manufacturers Association
of America, Inc.

74



CMAA Specification #74, Revised 2015
Supersedes Specification #74, Revised 2010



CMAA is an affiliate of MHI

CMAA SPECIFICATION NO. 74-2015
SPECIFICATIONS FOR TOP RUNNING AND UNDER RUNNING SINGLE GIRDER
ELECTRIC TRAVELING CRANES UTILIZING UNDER RUNNING TROLLEY HOIST

INTRODUCTION

This Specification has been developed by the Crane Manufacturers Association of America, Inc. (CMAA), an organization of leading electric overhead traveling crane manufacturers in the United States, for the purpose of promoting standardization and providing a basis for equipment selection. The use of this Specification should not limit the ingenuity of the individual manufacturer but should provide guidelines for technical procedure.

In addition to Specifications, the publication contains information which could be helpful to the purchasers and users of cranes and to the engineering and architectural professions. While much of this information must be of a general nature, it may be checked with individual manufacturers, and comparisons may be made, leading to the selection of the proper equipment.

These Specifications consist of eight Sections, as follows:

- 74-1 General Specifications
- 74-2 Crane Classification
- 74-3 Structural Design
- 74-4 Mechanical Design
- 74-5 Electrical Equipment
- 74-6 Inquiry Data Sheet and Speeds
- 74-7 Glossary
- 74-8 Index

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SUMMARY OF CHANGES SINCE THE 2010 REVISION OF SPECIFICATION #74

Added the "CMAA Specification Interpretation Request Procedure" on page 5.

Section 1.4.1.1.5..... L_r defined for cantilevered runway Sections

Section 1.4.1.2.3.....Maximum wheel load definition added for cantilevered Sections

Section 1.4 and Table 1.4.2-1.....Revised to specifically address crane runways

Section 1.5.8.....New Section for Runway Current Collectors

Section 1.5.9.....New Section for Runway Grounding Conductor

Section 3.3.2.2.1.....Revised Section for operational wind loading

Sections 3.3.2.5 & 3.7.3.....Reference to stress levels removed

Section 3.3.2.6.1.....Added maximum value for λ

Section 3.3.2.6.3.....Added to Section to consider internal diaphragm stresses

Table 3.4.7-2A.....Revised the Table to specify types of testing required for certain weld types

Figure 3.4.7-2B.....Updated

Section 3.4.8.3.....Revised design factor equations

Section 3.5.1.....Revised Section for proportions for welded box girders.

Section 3.5.4.1.....Revised to include errata issued for 2010 edition

Section 3.5.5.4.....Revised to add lateral deflection limits

Section 3.9.3.....New Section for gantry stability

Sections 4.2.2 & 4.2.3.....Revised gear quality classification Section

Section 5.2.8.1.3.3.....Revised to include errata issued for 2004 edition

Section 5.4.7.4.....New Section for Control System Markings

Section 5.5.....Revised Section for Resistors

Section 5.6.16.....New Section for Lightning Protection

Section 5.6.17.....New Section for Below-the-Hook Devices

Sections 5.9.3.1-5.9.3.3.....New Sections for Power Circuit Limit Switches

Section 5.14.....Revised Section for Inverters

Section 5.16.....New Section for Collision Avoidance

Section 5.17.....New Section for Weigh Scale Systems

Miscellaneous improvements:

- * Commentary has been provided to newly added or revised Sections.
- * Improved cross-referencing between main Sections.
- * Improved formatting.

CMAA SPECIFICATION INTERPRETATION REQUEST PROCEDURE

A request for interpretation of CMAA's specifications is to be designated as an "Action Alert Inquiry."

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1. CMAA assigns an Action Alert Inquiry number to each written inquiry.
2. CMAA immediately forwards the inquiry to the CMAA Engineering Vice President. Based on the nature and substance of the inquiry, the Vice President selects either a non-balloted or balloted response. Non-balloted responses generally will be selected for simple obvious replies and for inquiries to be declined. Inquiries for interpretation of CMAA Specifications 70, 74 and 78 will be balloted.
3. Response time for inquiries typically range from one week to one month, if balloted.

This Specification is accompanied by explanatory commentaries.

The commentaries in this Specification are not a part of the Specification and do not constitute a formal interpretation of the Specification (which can be obtained only through requests as indicated above). The commentaries, therefore, solely reflect the personal opinions of the editor or other contributors and do not necessarily represent the official position of CMAA or its technical committees.

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74-1 GENERAL SPECIFICATIONS

1.1 SCOPE

- 1.1.1 These Specifications shall be known as the Specifications for Top Running and Under Running Single Girder Electric Overhead Traveling Cranes Utilizing Under Running Trolley Hoist. CMAA Specifications No. 74 - Revised 2015.
- 1.1.2 The Specifications and information contained in this publication apply to top running and under running single girder electric overhead traveling cranes utilizing under running trolley hoist except patented track. It should be understood that the Specifications are general in nature and other Specifications may be agreed upon between the purchaser and the manufacturer to suit each specific installation. ***These Specifications do not cover equipment used to lift, lower or transport personnel suspended from the hoist rope system.***
- 1.1.3 These Specifications outline, in Chapter [74-2](#), four different classes of crane service as a guide for determining the service requirements of the individual application. In many cases, there is no clear category of service in which a particular crane operation may fall, and the proper selection of a crane can be made only through a discussion of service requirements and the crane details with the crane manufacturer or other qualified persons.
- 1.1.4 Service conditions have an important influence on the life of the wearing parts of a crane such as wheels, gears, bearings, and electrical equipment, and must be considered in specifying a crane to assure maximum life and minimum maintenance.
- 1.1.5 In selecting overhead crane equipment, it is important that not only present but future operations be considered which may increase loading and service requirements and that equipment be selected which will satisfy future increased service conditions, thereby minimizing the possibility of overloading or placing in a duty classification higher than intended.
- 1.1.6 Parts of these Specifications refer to certain portions of other applicable Specifications, codes or standards. Where interpretations differ, CMAA recommends that these Specifications be used as the guideline. Mentioned in the text are publications of the following organizations:
- | | |
|------|--|
| ABMA | American Bearing Manufacturers Association
2025 M Street, N.W., Suite 800
Washington, DC 20036-3309 |
| AGMA | American Gear Manufacturers Association
1001 N. Fairfax Street, Suite 500
Alexandria, VA 22314-1587

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

ANSI/AGMA 2000-A88 Gear Classification and Inspection Handbook – Tolerances and Measuring Methods for Unassembled Spur and Helical Gears

ANSI/AGMA 2015-1-A01 Accuracy Classification System – Tangential Measurements for Cylindrical Gears |
| AISC | American Institute of Steel Construction
One East Wacker Drive, Suite 700
Chicago, IL 60601-1802

AISC 9 th Edition ASD |
| AIST | Association for Iron and Steel Technology
186 Thorn Hill Rd
Warrendale, PA 15086

Technical Report TR-01-1991 |

ANSI	American National Standards Institute 25 West 43rd Street New York, NY 10036 ANSI A14.3-2008 – Safety Requirements for Fixed Ladders and Workplace Surfaces ANSI C84.1-2011 – Electric Power Systems and Equipment Voltage Ratings (60 Hz)
ASCE	The American Society of Civil Engineers 1801 Alexander Bell Drive Reston, VA 20191 ASCE/SEI 7-10 - Minimum Design Loads for Buildings and Other Structures
ASME	American Society of Mechanical Engineers Two Park Avenue New York, NY 10016-5990 ASME B30.11-2010- Monorails and Underhung Cranes ASME B30.16-2012 - Overhead Hoists (Underhung) ASME B30.17-2006 - Overhead and Gantry Cranes (Top Running, Single Girder, Underhung Hoist)
ASTM	American Society of Testing and Materials 100 Barr Harbor Drive, P.O. Box C700 West Conshohocken, PA 19428-2959
AWS	American Welding Society 8669 NW 36 Street, #30 Miami, FL 33166-6672 D14.1-97 - Specifications for Welding Industrial and Mill Cranes and Other Material Handling Equipment
CMAA	Crane Manufacturers Association of America, Inc. 8720 Red Oak Blvd., Suite 201 Charlotte, NC 28217-3996 Overhead Crane Inspection and Maintenance Checklist Crane Operator's Manual Crane Operator's Training Video
ECMA	Electrification and Controls Manufacturers Association 8720 Red Oak Blvd., Suite 201 Charlotte, NC 28217-3996 ECMA 15 2013 – Specification for Cable-less Controls for Electric Overhead Traveling Cranes ECMA 25 2012 – Specification for AC Inverters for use on Electric Overhead, Monorail, and Gantry Traveling Cranes
IEEE	Institute of Electrical and Electronic Engineers 445 Hoes Lane Piscataway, NJ 08854 IEEE Standard 141-1993 – Recommended Practice for Electric Power Distribution for Industrial Plants
NEC	National Electric Code (NFPA 70)
NFPA	National Fire Protection Association 1 Batterymarch Park Quincy, MA 02269-7471 NFPA 70 – National Electrical Code, 2014 Edition

- 1.3.2 Clearance shall be maintained between the crane and the building, as well as parallel running cranes, under all normal operating conditions. In the design of new cranes, all factors that influence clearance, such as wheel float, bridge skewing, or trolley positions and configurations shall be considered. As a minimum, the clearance between the end of the crane and the closest side obstruction shall not be less than 2 inches with crane centered on runway rails. Pipes, conduits, lights, etc., must not reduce this clearance.
- 1.3.3 Where passageways or walkways are provided on the structure supporting the crane, obstructions on the supporting structure shall not be placed so that personnel will be struck by movement of the crane. The accuracy of building dimensions is the responsibility of the owner or specifier of the equipment.

1.4 CRANE RUNWAY

- 1.4.1 The crane runway, runway rails, and crane stops are typically furnished by the purchaser unless otherwise specified. The crane stops furnished by the purchaser are to be designed to suit the specific crane to be installed.

1.4.1.1 Top Running Runway

- 1.4.1.1.1 Rails shall be straight, parallel, level, at the same elevation and at the specified center to center distance, within the tolerances given in Table [1.4.1-1](#).
- 1.4.1.1.2 The runway rails should be standard rail sections, or other commercial rolled section with equivalent specifications and of a proper size for the crane to be installed.
- 1.4.1.1.3 Crane rail splices shall be bolted or welded. Rail joints on opposite sides of the runway should be staggered. Properly selected hold-down devices shall be used to anchor the rail to the runway. Lateral "floating" type rail fastening is not recommended.
- 1.4.1.1.4 Rail joint misalignment can be a significant factor in wheel, axle, and bearing failures. It is recommended that horizontal rail separation at joints not exceed 1/16 inch. Vertical and horizontal alignment at joints should be maintained as closely as possible. Rail joints should be ground flush as necessary to provide a smooth transition from each rail segment to the next.
- 1.4.1.1.5 The crane runway shall be designed with sufficient strength and rigidity to prevent detrimental lateral or vertical deflection.

The lateral deflection should not exceed $L_r/400$ based on 10% of maximum wheel load(s) without *VIF*. Unless otherwise specified, the vertical deflection should not exceed $L_r/600$ based on maximum wheel load(s) without *VIF*. Gantry and other types of special cranes may require additional considerations.

L_r = Runway girder span being evaluated.

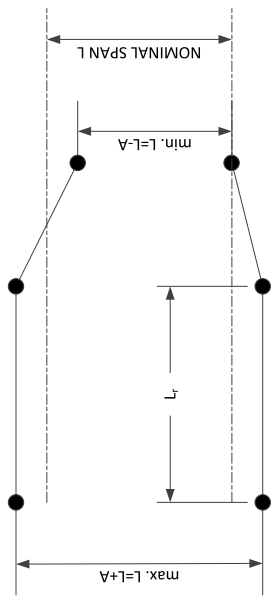
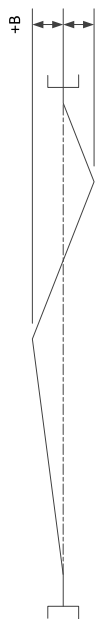
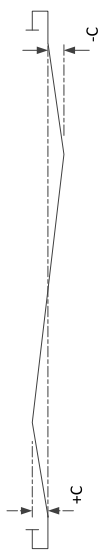
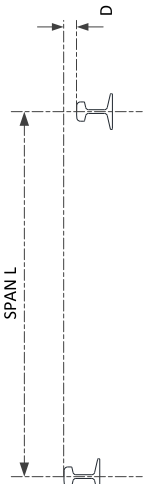
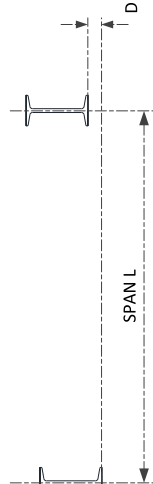
In the case of cantilevered runway beams, L_r is defined as the distance from the last support to the farthest wheel. The end slope of cantilevers should be calculated and considered in horsepower and wheel traction calculations.

1.4.1.2 Under-Running Runways

- 1.4.1.2.1 Under-running runway beams shall be straight, parallel, level, at the same elevation and at the specified center to center distance, within the tolerances given in Table [1.4.1-1](#).
- 1.4.1.2.2 Runway joint misalignment can be a significant factor in wheel, axle, and bearing failures. It is recommended that horizontal rail separation at runway joints not exceed 1/16 inch. Vertical, horizontal and transverse tilt of the wheel running surface at joints shall be aligned as closely as possible. Runway joints should be ground flush as necessary to provide a smooth transition from each runway beam segment to the next.
- 1.4.1.2.3 The crane runway shall be designed with sufficient strength and rigidity to prevent detrimental lateral or vertical deflection. The design shall provide for the effects of beam loading and local flange loading. The vertical deflection should not exceed $L_r/450$ based on maximum wheel load(s) without *VIF*.

In the case of cantilevered runway beams, L_r is defined as the distance from the last support to the farthest wheel. The end slope of cantilevers should be calculated and considered in horsepower and wheel traction calculations.

TABLE 1.4.1-1 – CRANE RUNWAY RAIL TOLERANCES

ITEM	FIGURE	OVERALL TOLERANCE	MAXIMUM RATE OF CHANGE
CRANE SPAN (<i>L</i>) MEASURED AT CRANE WHEEL CONTACT SURFACE		$L \leq 50'$ $A = \frac{3}{16}"$	$\frac{1}{4}" / 20' - 0"$
		$50' < L \leq 100'$ $A = \frac{3}{16}"$	
		$L > 100'$ $A = \frac{3}{8}"$	
STRAIGHTNESS (<i>B</i>)		$B = \frac{3}{8}"$	$\frac{1}{4}" / 20' - 0"$
ELEVATION (<i>C</i>)		$C = \frac{3}{8}"$	$\frac{1}{4}" / 20' - 0"$
TOP RUNNING TRANSVERSE RAIL-TO-RAIL ELEVATION (<i>D</i>)		$L \leq 50'$ $D = \pm \frac{3}{16}"$	$\frac{1}{4}" / 20' - 0"$
UNDER RUNNING TRANSVERSE GIRDER-TO-GIRDER ELEVATION (<i>D</i>)		$50' < L \leq 100'$ $D = \pm \frac{1}{4}"$	
		$L > 100'$ $D = \pm \frac{3}{8}"$	

1.5 RUNWAY CONDUCTORS

- 1.5.1 The runway conductors may be bare hard drawn copper wire, hard copper, aluminum or steel in the form of stiff shapes, insulated cables, cable reel pickup or other suitable means to meet the particular application and shall be installed in accordance with Article 610 of the National Electric Code and comply with all applicable codes.
- 1.5.2 Contact conductors shall be guarded in a manner that persons cannot inadvertently touch energized current-carrying parts. Flexible conductor systems shall be designed and installed in a manner to minimize the effects of flexing, cable tension, and abrasion.
- 1.5.3 Runway conductors are normally furnished and installed by the purchaser unless otherwise specified.
- 1.5.4 The conductors shall be properly supported and aligned horizontally and vertically with the runway rail.
- 1.5.5 The conductors shall have sufficient ampacity to carry the required current to the crane, or cranes, when operating with rated load. The conductor ratings shall be selected in accordance with Article 610 of the National Electrical Code. 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 sum total which will permit the application of the intermittent ampacity ratings for use with continuous fixed loads.
- 1.5.6 The nominal runway conductor supply system voltage, actual input tab voltage, and runway conductor voltage drops shall result in crane motor voltage tolerances per Section [5.13](#) Voltage Drops.
- 1.5.7 In a crane inquiry, the runway conductor system type should be specified and whether the system will be supplied by the purchaser or crane manufacturer. If supplied by the purchaser, the location should be stated.
- 1.5.8 Current collectors, if used, shall be compatible with the type of contact conductors furnished. The collector rating shall be sized for the crane ampacity as computed by Article 610 of the National Electrical Code. A minimum of two (2) collectors for each runway conductor shall be furnished when the crane is used with a lifting magnet. Refer to Section [5.14.7](#) for additional requirements and recommendations when using inverters.
- 1.5.9 For grounding purposes in new runway installations, a separate grounding conductor shall be provided.

Commentary: OSHA states in 29 CFR 1910.304(g)(5) & (g)(7) that "the path to ground from the circuits, equipment and enclosures shall be permanent, continuous and effective."

The National Electric Code includes a general prohibition on grounding equipment through the bridge and trolley wheels. CMAA requires a separate grounding conductor on all new runway conductor systems.

1.6 RATED CAPACITY

- 1.6.1 The rated capacity of a crane bridge is specified by the manufacturer. This capacity shall be marked on each side of the crane bridge and shall be legible from the operating floor.
- 1.6.2 Individual hoist units shall have their rated capacity marked on their bottom block. In addition, capacity label should be marked on the hoist body.
- 1.6.3 The total lifted load shall not exceed the rated capacity of the crane bridge. Load on individual hoists or hooks shall not exceed their rated capacity.
- 1.6.4 When determining the rated capacity of a crane, all accessories below the hook, such as load bars, magnets, grabs, etc., shall be included as part of the load to be handled.

1.7 DESIGN STRESSES

- 1.7.1 Materials shall be properly selected for the stresses and work cycles to which they are subjected.
- 1.7.2 Structural parts shall be designed according to the appropriate limits as per Chapter [74-3](#) of this Specification. Mechanical parts shall be designed according to Chapter [74-4](#) of this Specification. All other load carrying parts shall be designed so that the calculated static stress in the material, based on rated crane capacity, shall not exceed 20 percent of the published average ultimate strength of the material.
- 1.7.3 The limitation of stress provides a margin of strength to allow for variations in the properties of materials, manufacturing and operating conditions, and design assumptions, and under no condition should imply authorization or protection for users loading the crane beyond the rated capacity.

1.8 GENERAL

- 1.8.1 All apparatus covered by this Specification shall be constructed in a thorough and workmanlike manner. Due regard shall be given in the design for operation, accessibility, interchangeability and durability of parts.

- 1.8.2 This Specification includes all applicable features of OSHA Section 1910.179 - Overhead and Gantry Cranes; ASME B30.11 - Monorails and Underhung Cranes; ASME B30.16 - Overhead Hoists (Underhung); and ASME B30.17 - Overhead and Gantry Cranes (Top Running, Single Girder, Underhung Hoist).

1.9 PAINTING

- 1.9.1 Before shipment, the crane shall be cleaned and given a protective coating.
- 1.9.2 The coating may consist of any number of coats of primer and finish paint according to the manufacturer's standard or as otherwise specified.

1.10 ASSEMBLY AND PREPARATION FOR SHIPMENT

- 1.10.1 The crane should be assembled in the manufacturer's plant according to the manufacturer's standard. When feasible, the trolley should be placed on the assembled crane bridge; the hoisting rope is not normally reeved unless otherwise specified.
- 1.10.2 All parts of the crane should be carefully match-marked.
- 1.10.3 All exposed finished parts and electrical equipment are to be protected for shipment. If storage is required, arrangements should be made with the manufacturer for extra protection.

1.11 TESTING

- 1.11.1 Testing in the manufacturer's plant is conducted according to the manufacturer's testing procedure, unless otherwise specified.
- 1.11.2 Any documentation of nondestructive testing of material such as X-ray, ultrasonic, magnetic particle, etc. should be considered as an extra item and is normally done only if specified.

1.12 DRAWINGS AND MANUALS

Normally two (2) copies of the manufacturer's clearance diagrams are submitted for approval, one of which is approved and returned to the crane manufacturer. Also, two (2) sets of operating instructions and spare parts information are typically furnished. Detail drawings are normally not furnished.

1.13 ERECTION

The crane erection (including assembly, field wiring, installation and starting) is normally agreed upon between the manufacturer and the owner or specifier. Supervision of field assembly and/or final checkout may also be agreed upon separately between the manufacturer and the owner or specifier.

1.14 LUBRICATION

The crane shall be provided with all the necessary lubrication fittings. Before putting the crane in operation, the erector of the crane shall assure that all bearings, gears, etc. are lubricated in accordance with the crane manufacturer's recommendations.

1.15 INSPECTION, MAINTENANCE AND CRANE OPERATOR TRAINING

- 1.15.1 For inspection and maintenance of cranes, refer to applicable Section of ASME B30.11 Chapter 11-2, ASME B30.17 Chapter 17-2, CMAA - Specification No. 78, and CMAA - Overhead Crane Inspection and Maintenance Checklist.
- 1.15.2 For operator responsibility and training, refer to applicable Section ASME B30.11 Chapter 11-3, ASME B30.17 Chapter 17-3, CMAA - Crane Operator's Training Video and CMAA - Crane Operator's Manual - Specification No. 79.

74-2 CRANE CLASSIFICATIONS

2.1 GENERAL

- 2.1.1 Service classes have been established so that the most economical crane for the installation may be specified in accordance with this Specification.
- 2.1.2 The crane service classification is based on the load spectrum reflecting the actual service conditions as closely as possible.
- 2.1.3 Load spectrum is a mean effective load, which is uniformly distributed over a probability scale and applied to the equipment at a specified frequency. The selection of the properly sized crane component to perform a given function is determined by the varying load magnitudes and given load cycles; this can be expressed in terms of the mean effective load factor.

$$k = \sqrt[3]{(W_1)^3 P_1 + (W_2)^3 P_2 + (W_3)^3 P_3 + \cdots (W_n)^3 P_n}$$

where: W = Load magnitude; expressed as a ratio of each lifted load to the rated capacity. Operation with no lifted load and the weight of any attachment must be included.

P = Load probability; expressed as a ratio of cycles under each load magnitude condition to the total cycles. The sum total of the load probabilities P must equal 1.0.

k = Mean effective load factor. (Used to establish crane service class only)

- 2.1.4 All classes of cranes are affected by the operating conditions, therefore for the purpose of the classifications, it is assumed that the crane will be operating in normal ambient temperature 0° to 104°F (−17.8° to 40°C) and normal atmospheric conditions (free from excessive dust, moisture and corrosive fumes).
- 2.1.5 The cranes can be classified into loading groups according to the service conditions of the most severely loaded part of the crane. The individual parts which are clearly separate from the rest, or forming a self-contained structural unit, can be classified into different loading groups if the service conditions are fully known.

2.2 CLASS A (STANDBY OR INFREQUENT SERVICE)

This service class covers cranes which may be used in installations such as powerhouses, public utilities, turbine rooms, motor rooms and transformer stations where precise handling of equipment at slow speeds with long, idle periods between lifts are required. Capacity loads may be handled for initial installation of equipment and for infrequent maintenance.

2.3 CLASS B (LIGHT SERVICE)

This service covers cranes which may be used in repair shops, light assembly operations, service buildings, light warehousing, etc., where service requirements are light and the speed is slow. Loads may vary from no load to occasional full rated loads with 2 to 5 lifts per hour, averaging 10 feet per lift.

2.4 CLASS C (MODERATE SERVICE)

This service covers cranes which may be used in machine shops or papermill machine rooms, etc., where service requirements are moderate. In this type of service the crane will handle loads which average 50 percent of the rated capacity with 5 to 10 lifts per hour, averaging 15 feet, not over 50 percent of the lifts at rated capacity.

2.5 CLASS D (HEAVY SERVICE)

This service covers cranes which may be used in heavy machine shops, foundries, fabricating plants, steel warehouses, container yards, lumber mills, etc., and standard duty bucket and magnet operations where heavy duty production is required. In this type of service, loads approaching 50 percent of the rated capacity will be handled constantly during the working period. High speeds are desirable for this type of service with 10 to 20 lifts per hour averaging 15 feet, not over 65 percent of the lifts at rated capacity.

2.6 CRANE SERVICE CLASS IN TERMS OF LOAD CLASS AND LOAD CYCLES

The definition of CMAA crane service class in terms of load class and load cycles is shown in Table [2.6-1](#).

TABLE 2.6-1
DEFINITION OF CMAA CRANE SERVICE CLASS
IN TERMS OF LOAD CLASS AND LOAD CYCLES

LOAD CLASS	LOAD CYCLES				<i>k</i> = MEAN EFFECTIVE LOAD FACTOR
	N ₁	N ₂	N ₃	N ₄	
L ₁	A	B	C	D	0.35 – 0.53
L ₂	B	C	D	E	0.531 – 0.67
L ₃	C	D	E	F	0.671 – 0.85
L ₄	D	E	F	F	0.851 – 1.00
	Irregular occasional use followed by long idle periods	Regular use in intermittent operation	Regular use in continuous operation	Regular use in severe continuous operation	

LOAD CLASSES:

- L₁ = Cranes which hoist the rated load exceptionally and normally, very light loads.
- L₂ = Cranes which rarely hoist the rated load, and normal loads of about 1/3 of the rated load.
- L₃ = Cranes which hoist the rated load fairly frequently and normally, loads between 1/3 and 2/3 of the rated load.
- L₄ = Cranes which are regularly loaded close to the rated load.

LOAD CYCLES

- N₁ = 20,000 to 100,000 cycles
- N₂ = 100,000 to 500,000 cycles
- N₃ = 500,000 to 2,000,000 cycles
- N₄ = Over 2,000,000 cycles

74-3 STRUCTURAL DESIGN

3.1 MATERIAL

All structural steel should conform to ASTM-A36 or A992 Specifications, or shall be an accepted type for the purpose for which the steel is to be used and for the operations to be performed on it. Other suitable materials may be used provided that the parts are proportioned to comparable design factors.

3.2 WELDING

All welding designs and procedures shall conform to AWS D14.1, "Specification for Welding Industrial and Mill Cranes". Weld stresses determined by load combination Case 1, Sections [3.3.2.5.1](#) and [3.4.4.3](#), shall not exceed that shown in the applicable Section [3.4.1](#) or Table [3.4.7-1](#). Allowable weld stresses for load combination Cases 2 and 3, Sections [3.3.2.5.2](#) and [3.3.2.5.3](#) are to be proportioned in accordance with Sections [3.4.2](#) and [3.4.3](#).

3.3 STRUCTURE

3.3.1 General

The crane girder shall be welded structural steel box section, wide flange beam, standard I beam, reinforced beam or a section fabricated from structural plates and shapes. The manufacturer shall specify the type and the construction to be furnished. Camber and sweep should be measured by the manufacturer prior to shipment.

3.3.2 Loadings

The crane structures are subjected, in service, to repeated loading varying with time which induces variable stresses in members and connections through the interaction of the structural system and the cross-sectional shapes. The loads acting on the structure are divided into three different categories. All the loads having an influence on engineering strength analysis are regarded as principal loads, namely the dead loads, which are always present; the hoist load, acting during each cycle; and the inertia forces acting during the movements of cranes, crane components, and hoist loads. Load effects, such as operating wind loads, skewing forces, snow loads, temperature effects, are classified as additional loads and are only considered for the general strength analysis and in stability analysis. Other loads such as collision, out of service wind loads, and test loads applied during the load test are regarded as extraordinary loads and except for collision and out of service wind loads are not part of the Specification. Seismic forces are not considered in this design Specification. However, if required, accelerations shall be specified at the crane rail elevation by the owner or specifier. The allowable stress levels under this condition of loading shall be agreed upon with the crane manufacturer.

3.3.2.1 Principal Loads

3.3.2.1.1 Dead Load (*DL*)

The weight of all effective parts of the bridge structure, the machinery parts and the fixed equipment supported by the structure.

3.3.2.1.2 Trolley Load (*TL*)

The weight of the trolley and the equipment attached to the trolley.

3.3.2.1.3 Lifted Load (*LL*)

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

3.3.2.1.4 Vertical Inertia Forces (*VIF*)

The vertical inertia forces (*VIF*) include those due to the motion of the cranes or the crane components and those due to lifting or lowering of the hoist load. These additional loadings may be included in a simplified manner by the application of a separate factor for the dead load (*DLF*) and for the hoist load (*HLF*) by which the vertical acting loads, the member forces or the stresses due to them must be multiplied.

3.3.2.1.4.1 Dead Load Factor (*DLF*)

This factor covers only the dead loads of the crane, trolley and its associated equipment and shall be taken according to:

$$DLF = 1.1 \leq 1.05 + \frac{\text{Travel Speed (ft/min)}}{2000} \leq 1.2$$

3.3.2.1.4.2 Hoist Load Factor (*HLF*)

The hoist load factor shall be applied to the lifted load (*LL*) in the vertical direction, and is the result of normal operating inertia forces, loads due to the sudden lifting of the load, and other loading uncertainties that occur during normal crane operation.

The *HLF* for normal operating cranes, including cranes using permanent magnets or other devices that do not result in abrupt handling of the load, shall be 0.5 percent of the hoisting speed in feet per minute, but not less than 15 percent nor more than 50 percent.

$$HLF = 0.15 \leq 0.005 \times \text{Hoist Speed (ft/min)} \leq 0.5$$

The *HLF* for cranes used for loads that are abruptly engaged shall be at least 50% of the lifted load (*LL*). Examples of such applications include (but are not limited to) cranes used with buckets, electromagnets, or grapples.

3.3.2.1.5 Inertia Forces From Drives (*IFD*)

Travel drive inertia forces result from the acceleration or deceleration of the crane bridge or trolley, and depend on the magnitude of torque applied to the drive wheels. This force shall be determined by applying an *IFD* factor to the lifted load and weight of the crane components, including attachments, and shall be imposed on the crane in the direction of bridge and trolley travel.

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

$$\begin{aligned} IFD \text{ Factor} &= (2.50/32.2) \times \text{Acceleration or Deceleration Rate (ft/s}^2\text{)} \geq 0.025 \\ &= 0.078 \times \text{Acceleration or Deceleration Rate (ft/s}^2\text{)} \geq 0.025 \end{aligned}$$

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

3.3.2.2 Additional Loads

3.3.2.2.1 Operating Wind Load (*WLO*)

Unless otherwise specified, the lateral operational load due to wind on outdoor cranes shall be considered as 5 pounds per square foot on the projected area exposed to the wind, which is based on an effective combined wind speed of 44 miles per hour (i.e. Operational wind speed plus crane travel speed). The wind areas of the girder and trolley shall be considered to be 1.6 times their projected areas, and for single surfaces, such as cabs, gantry legs, lifted loads or machinery enclosures, the wind area shall be considered to be 1.2 (or the applicable shape factor/force coefficient specified by ASCE/SEI 7) times the projected area to account for negative pressure on the leeward side of the structure. For gantry crane legs the wind load shall be applied to all legs due to variations in wind direction.

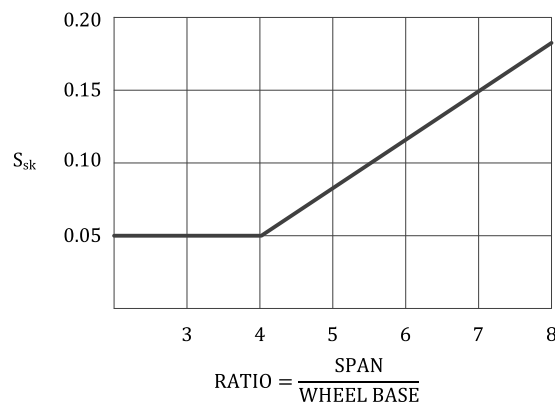
When the projected area of the lifted load is not specified by the purchaser/owner, the following area should be used, which includes consideration of a 1.2 shape factor, where '*RL*' is the crane's Rated Load in Tons:

$$\text{Wind Area of the Rated Load (ft}^2\text{)} = 5 \times (RL)^{2/3}$$

Commentary: To provide a basis for the mechanical and structural design, CMAA includes a default value for projected area of the lifted load when no other design criteria is specified. The intent is to remove ambiguity for projected area considerations. The constant of 5 in the lifted load projected area formula is based on the lifted load being a cubical shape and has an approximate density of 50% that of steel (496 lb/ft^3) and has a 1.2 shape factor. The value is determined by equating the area of the face of a cube in terms of the cube's weight and applying the 1.2 shape factor (i.e.: $1.2 \times (2000 \times 2/496)^{2/3} = 4.82$, rounded to 5). The area multipliers of 1.2 and 1.6 are considered to be reasonable shape factors for typical overhead crane designs. Trolleys with multiple exposed surfaces must use the 1.6 shape factor, whereas a 1.2 shape factor is reasonable for totally enclosed trolleys.

3.3.2.2.2 Forces due to Skewing (SK)

When wheels roll along a rail, the horizontal forces normal to the rail tend to skew the structure and shall be taken into consideration. The horizontal forces shall be obtained by multiplying the vertical load exerted on each wheel by coefficient S_{sk} which depends upon the ratio of the span to the wheel base. The wheel base is the distance between the outermost wheels.



3.3.2.3 Extraordinary Loads

3.3.2.3.1 Stored Wind Load (WLS)

This is the maximum wind that a crane is designed to withstand during out of service condition. The speed and test pressure varies with the height of the crane above the surrounding ground level, geographical location and degree of exposure to prevailing winds (See ASCE/SEI 7 as applicable).

3.3.2.3.2 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 stroke. Load suspended from the lifting equipment and free oscillating load 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 released on the collision of two cranes with the moving masses of M_1 , M_2 , and a 40 percent maximum traveling speed of V_{T1} and V_{T2} shall be determined from the following equation:

$$E = \frac{M_1 M_2 (0.4V_{T1} + 0.4V_{T2})^2}{2(M_1 + M_2)}$$

The bumper forces shall be distributed in accordance with the bumper characteristics and the freedom of the motion of the structure with the trolley in its worst position.

Should the crane application require that maximum deceleration rates and/or stopping forces 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 should be defined at the time of the crane purchase.

3.3.2.4 Torsional Forces and Moments

3.3.2.4.1 Due to the Starting and Stopping of the 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 percent of full load torque multiplied by the gear ratio between the motor and cross shaft.

- 3.3.2.4.2 Due to Vertical Loads:
Torsional moment due to vertical forces acting eccentric 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.
- 3.3.2.4.3 Due to Lateral Loads:
The torsional moment due to the lateral forces acting eccentric 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.
- 3.3.2.5 Load Combination
The combined stresses shall be calculated for the following design cases:
- 3.3.2.5.1 Case 1: Crane in regular use under principal loading
 $DL(DLF_B) + TL(DLF_T) + LL(1 + HLF) + IFD$
- 3.3.2.5.2 Case 2: Crane in regular use under principal and additional loading
 $DL(DLF_B) + TL(DLF_T) + LL(1 + HLF) + IFD + WLO + SK$
- 3.3.2.5.3 Case 3: Extraordinary Loads
- 3.3.2.5.3.1 Crane subjected to out of service wind
 $DL + TL + WLS$
- 3.3.2.5.3.2 Crane in collision
 $DL + TL + WLS + LL + CF$
- 3.3.2.5.3.3 Test Loads
CMAA recommends test load not exceed 125 percent of rated load.
- 3.3.2.6 Local Bending of Flanges Due to Wheel Loads
- 3.3.2.6.1 Each wheel load shall be considered as a concentrated load applied at the center of wheel contact with the flange (Figure 3.3.2.6-1). Local flange bending stresses in the lateral (x) and longitudinal (y) direction at certain critical points may be calculated from the following formulas:
- Underside of flange at flange-to-web transition—Point 0:
- $$\sigma_{X0} = C_{X0} \frac{P}{(t_a)^2} \quad \sigma_{Y0} = C_{Y0} \frac{P}{(t_a)^2}$$
- Underside of flange directly beneath wheel contact point—Point 1:
- $$\sigma_{X1} = C_{X1} \frac{P}{(t_a)^2} \quad \sigma_{Y1} = C_{Y1} \frac{P}{(t_a)^2}$$
- Topside of flange at flange-to-web transition—Point 2:
- $$\sigma_{X2} = -\sigma_{X0} \quad \sigma_{Y2} = -\sigma_{Y0}$$
- For tapered flange sections (Figure 3.3.2.6-2)
- $$C_{X0} = -1.096 + 1.095\lambda + 0.192e^{-6.0\lambda}$$
- $$C_{X1} = 3.965 - 4.835\lambda - 3.965e^{-2.675\lambda}$$
- $$C_{Y0} = -0.981 - 1.479\lambda + 1.120e^{1.322\lambda}$$
- $$C_{Y1} = 1.810 - 1.150\lambda + 1.060e^{-7.70\lambda}$$
- $$t_a = t_f - \left[\frac{b}{24} \right] + \left[\frac{a}{6} \right] \quad \text{For standard 'S' section}$$
- where: t_f = published flange thickness for standard 'S' section (in)

For parallel flange section (Figure [3.3.2.6-3](#) & [3.3.2.6-4](#))

$$C_{X0} = -2.110 + 1.977\lambda + 0.0076e^{6.53\lambda}$$

$$C_{X1} = 10.108 - 7.408\lambda - 10.108e^{-1.364\lambda}$$

$$C_{Y0} = 0.050 - 0.580\lambda + 0.148e^{3.015\lambda}$$

$$C_{Y1} = 2.230 - 1.49\lambda + 1.390e^{-18.33\lambda}$$

For single web symmetrical sections (Figure [3.3.2.6-2](#) & [3.3.2.6-3](#))

$$\lambda = \frac{2a}{b - t_w} \leq 0.65$$

b = section width across flanges (*in*)

For other cases (Figure [3.3.2.6-4](#))

$$\lambda = \frac{2a}{b' - \frac{t_w}{2}} \leq 0.65$$

b' = distance from centerline of web to edge of flange (*in*)

where: P = Load per wheel including *HLF* (*lbs*)

t_a = Flange thickness at point of load application (*in*)

t_w = Web thickness (*in*)

a = Distance from edge of flange to point of wheel load application (*in*)
(Center of wheel contact)

e = Napierian base = 2.71828...

- 3.3.2.6.2 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 the Case 2 loading specified in Section [3.3.2.5.2](#) of this Specification.

When calculating the combined stress, the flange bending stresses for single web girders are to be diminished to 75% of the value calculated per Section [3.3.2.6.1](#).

The combined stress, as determined in Section [3.4.4.1](#), shall not exceed the Load Case 2 allowable stress in Table [3.4-1](#).

- 3.3.2.6.3 Additionally, in the case of welded plate girders only, the localized stresses on the topside of the flange at the flange-to-web transition (Point 2) are to be combined with the stresses due to the Case 2 loading specified in Section [3.3.2.5.2](#) of this Specification.

The combined stresses, in both the base metal of the welded joint and the weld metal at Point 2, as determined in Sections [3.4.4.2](#) and [3.4.4.3](#), shall not exceed the allowable stresses specified in Table [3.4-1](#) and Section [3.2](#), respectively. Nor shall the stress range exceed the allowable shown in Table [3.4.7-1](#) for joint category E.

The use of internal diaphragms within welded box girders that are loaded on the bottom flange may create stress concentration points in the weld between the bottom flange and the web plate. Consideration should be given to the lower flange weld near the locations of any internal diaphragms.

- 3.3.2.6.4 The local flange bending criteria per Section [3.3.2.6](#) is to be met in addition to the general criteria of Section [3.3.2.5](#) and Section [3.4](#).

- 3.3.2.6.5 At load transfer points, consideration should be given to lower flange stresses which are not calculable by the formulas presented in Section [3.3.2.6](#).

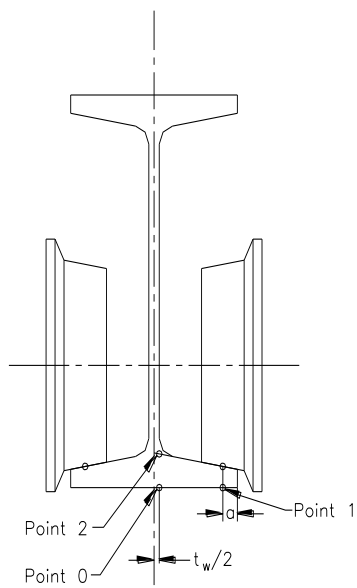


Figure 3.3.2.6-1

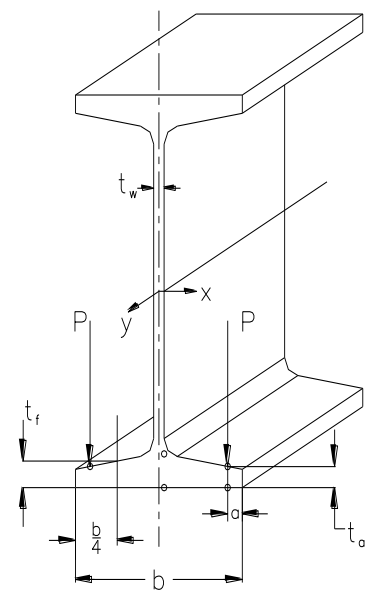


Figure 3.3.2.6-2

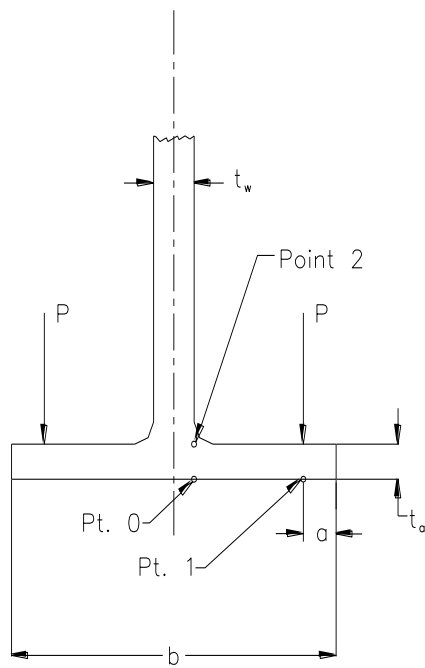
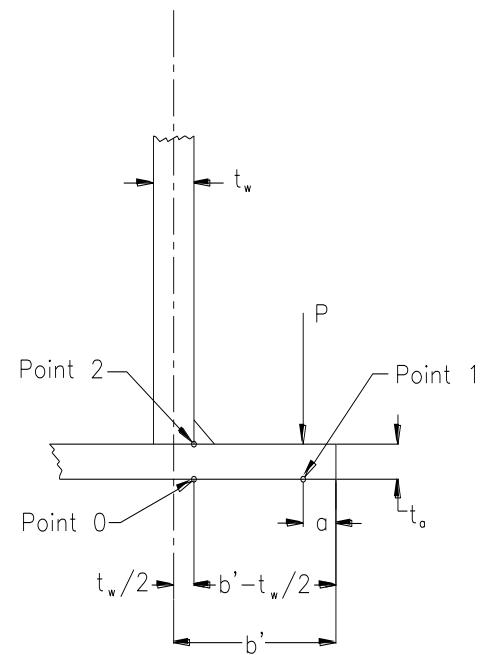


Figure 3.3.2.6-3



Lower Chord of a Box Girder
Figure 3.3.2.6-4