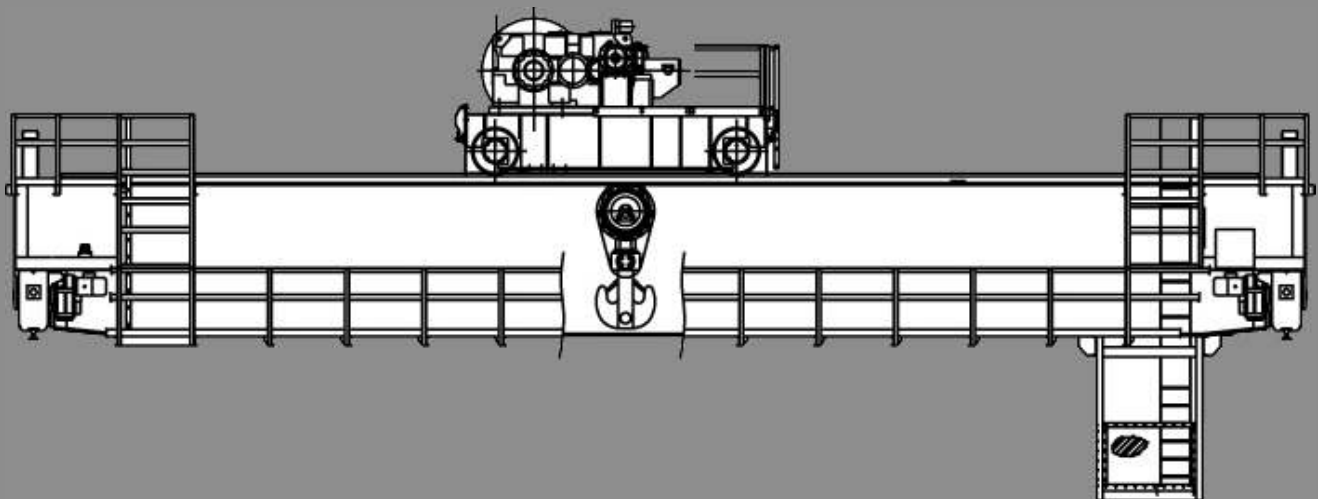


Specifications for Top Running Bridge & Gantry Type Multiple Girder Electric Overhead Traveling Cranes

Prepared by
The Crane Manufacturers Association
of America, Inc.



CMAA Specification #70, Revised 2015
Supersedes Specification #70, Revised 2010



MHI

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**CMAA SPECIFICATION NO. 70-2015
SPECIFICATIONS FOR TOP RUNNING BRIDGE AND GANTRY TYPE
MULTIPLE GIRDER ELECTRIC OVERHEAD TRAVELING CRANES**

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:

70-1	General Specifications
70-2	Crane Service Classification
70-3	Structural Design
70-4	Mechanical Design
70-5	Electrical Equipment
70-6	Inquiry Data Sheet and Speeds
70-7	Glossary
70-8	Index

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SUMMARY OF CHANGES SINCE THE 2010 REVISION OF SPECIFICATION #70

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

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

Section 1.4.6 L_r defined for cantilevered runway Sections.

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 3.3.2.6, 3.7 & 3.8.3 Reference to stress levels removed.

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 3.5.5.3 Revised to add lateral deflection limits

Sections 3.7 & 3.8 Revised to limit stresses to Case 2 Allowables

Section 3.10.2 Revised wording for bridge rail splices.

Section 3.13.3 New Section for Gantry Stability.

Sections 4.7.2 & 4.7.3 Revised gear quality classification Section

Section 5.4.7.4 New Section for Control System Markings

Section 5.5 Revised Section for Resistors

Section 5.6.17 New Section for lightning protection.

Section 5.6.18 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."

Only written inquiries about interpretations and the applicability of CMAA Specifications 70, 74 and 78 will be given a response by the CMAA Engineering and Safety Advocacy Workgroup. CMAA does not provide: design guidance, design critique, advice, comments on non-CMAA documents etc. Inquiries of this nature, if received, will be declined.

Send all written requests for interpretation of Specifications 70, 74 and 78, identifying the particular Specification and the Section numbers in question via email to cmaa-info@mhi.org or via Fax to 704-676-1199 to the attention of CMAA.

Interpretation requests must identify the sender by name, title, company name, address and telephone number and be on company letterhead. They must also be specific and concise.

The following is the CMAA procedure for processing and responding to interpretation requests.

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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70-1 GENERAL SPECIFICATIONS

1.1 SCOPE

- 1.1.1 This Specification shall be known as the Specifications for Top Running Bridge & Gantry Type Multiple Girder Electric Overhead Traveling Cranes - CMAA Specification No. 70 - Revised 2015.
- 1.1.2 The Specifications and information contained in this publication apply to top running bridge and gantry type multiple girder electric overhead traveling cranes. 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 This Specification outlines in Chapter [70-2](#) six 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 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, wire rope, 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 this Specification refer to certain portions of other applicable Specifications, codes or standards. Where interpretations differ, CMAA recommends that this Specification 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 ASC A14.3-2008 - Safety Requirements for Fixed Ladders and Workplace Surfaces ANSI C84.1-2011 - Electric Power Systems and Equipment Voltage Ratings (60Hz)
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	The American Society of Mechanical Engineers Two Park Avenue New York, NY 10016-5990 ASME B30.2-2011 - Overhead & Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist)
ASTM	American Society for Testing & 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 - Specification for Welding of 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 - Specification No 79-2012 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 Electronics Engineers 445 Hoes Lane Piscataway, NJ 08854 IEEE Standard 141-1993 - Recommended Practice for Electric Power Distribution for Industrial Plants
NFPA	National Fire Protection Association 1 Batterymarch Park Quincy, MA 02269-7471 NFPA 70 - National Electrical Code, 2014 Edition
NEMA	National Electrical Manufacturers Association 1300 North 17th Street, Suite 900 Arlington, VA 22209 ICS 1-2000 (R2005, R2008) - Industrial Control Systems and Electrical Requirements NEMA MG-1-2011 - Motors and Generators
OSHA	U.S. Department of Labor Directorate of Safety Standards Programs 200 Constitution Avenue, N.W. Washington, DC 20210 29 CFR Part 1910 - Occupational Safety & Health Standards for General Industry (Revised 7/1/97) Peterson's Stress Concentration Factors Walter D. Pilkey 2 nd Edition; 1997 Copyright John Wiley & Sons, Inc. OR Walter D. Pilkey & Deborah F. Pilkey 3 rd Edition; 2008 Data was utilized from (FEM) Federation Europeenne De La Manutention, Section I Heavy Lifting Equipment, Rules for the Design of Hoisting Appliances, 3rd Edition - October 1987.

1.2 BUILDING DESIGN CONSIDERATIONS

- 1.2.1 The building in which an overhead crane is to be installed must be designed with consideration given to the following points:
 - 1.2.1.1 The distance from the floor to the lowest overhead obstruction must be such as to allow for the required hook lift, plus the distance from the saddle or palm of the hook in its highest position to the high point on the crane, plus clearance to the lowest overhead obstruction.
 - 1.2.1.2 In addition, the distance from the floor to the lowest overhead obstruction must be such that the lowest point on the crane will clear all machinery or when necessary provide railroad or truck clearance under the crane.
 - 1.2.1.3 After determination of the building height, based on the factors above, the crane runway must be located with the top of the runway rail at a distance below the lowest overhead obstruction equal to the height of the crane plus clearance.
 - 1.2.1.4 Lights, pipes, or any other objects projecting below the lowest point on the building truss must be considered in the determination of the lowest overhead obstruction.
 - 1.2.1.5 The building knee braces must be designed to permit the required hook approaches.
 - 1.2.1.6 Access to the cab or bridge walkway should be a fixed ladder, stairs, or platform requiring no step over any gap exceeding 12 inches. Fixed ladders shall be in conformance with ANSI ASC A14.3-2008 – Safety Requirements for Fixed Ladders and Workplace Surfaces.

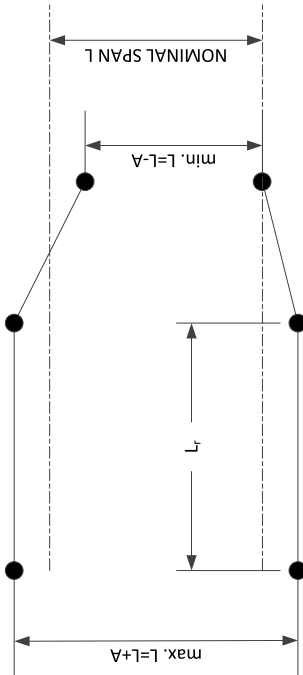
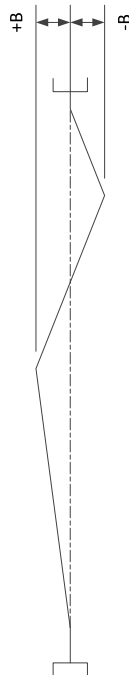
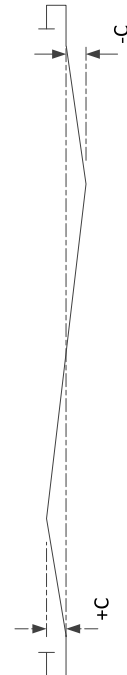
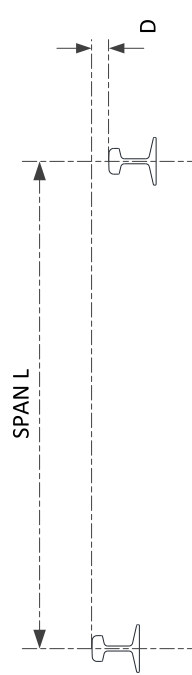
1.3 CLEARANCE

- 1.3.1 Clearance shall be maintained between the crane and the building, as well as cranes operating at different elevations, under all normal operating conditions. In the design of new cranes, all factors that influence clearance, such as roof / ceiling deflection, girder camber, trolley positions and configurations shall be considered. As a minimum, the clearance between the highest point of the crane and the lowest overhead obstruction shall not be less than 3 inches with the crane unloaded. Pipes, conduits, lights, etc., must not reduce this clearance.
- 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.
- 1.4.2 Rails shall be straight, parallel, level, at the same elevation and at the specified center to center distance, within the tolerances given in Table [1.4.2-1](#).
- 1.4.3 The runway rails should be standard rail sections, or other commercial rolled section of equivalent specifications and of a proper size for the crane. Rail sizes shall be selected in accordance with Section [4.13.3](#).
- 1.4.4 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.
- 1.4.5 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.

TABLE 1.4.2-1 – CRANE RUNWAY RAIL TOLERANCES

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

- 1.4.6 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 percent of maximum wheel load(s) without *VIF*. 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.

1.5 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 tap voltage, and runway conductor voltage drops shall result in crane motor voltage tolerances per Section [5.13](#) Voltage Drop.
- 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 [70-3](#) of this Specification. Mechanical parts shall be designed according to Chapter [70-4](#) 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 This 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; and ASME B30.2 - Safety Standard for Overhead and Gantry Cranes.

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

70-2 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.
- 2.1.2 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.

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

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 power houses, 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 two to five lifts per hour, averaging ten feet per lift.

2.4 CLASS C (MODERATE SERVICE)

This service covers cranes which may be used in machine shops or paper mill 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 CLASS E (SEVERE SERVICE)

This type of service requires a crane capable of handling loads approaching a rated capacity throughout its life. Applications may include magnet, bucket, magnet/bucket combination cranes for scrap yards, cement mills, lumber mills, fertilizer plants, container handling, etc., with twenty or more lifts per hour at or near the rated capacity.

2.7 CLASS F (CONTINUOUS SEVERE SERVICE)

This type of service requires a crane capable of handling loads approaching rated capacity continuously under severe service conditions throughout its life. Applications may include custom designed specialty cranes essential to performing the critical work tasks affecting the total production facility. These cranes must provide the highest reliability with special attention to ease of maintenance features.

2.8 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 [2.8-1](#).

TABLE 2.8-1
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

70-3 STRUCTURAL DESIGN

3.1 MATERIAL

All structural steel used 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 [3.3.2.6.1](#) and [3.4.4.2](#), 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 [3.3.2.6.2](#) and [3.3.2.6.3](#), are to be proportioned in accordance with Sections [3.4.2](#) and [3.4.3](#).

3.3 STRUCTURE

3.3.1 General

The crane girders shall be welded structural steel box sections, wide flange beams, standard I-beams, reinforced beams or sections 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 of 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 effect, loads on walkways, stairways, platforms and handrails 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 other supplemental devices.

3.3.2.1.4 Vertical Inertia Forces (*VIF*)

The vertical inertial forces include those due to the motion of the cranes or 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's 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 resulting inertia force, in the direction of bridge travel that corresponds to the trolley weight and lifted load, may be equally divided between the two bridge girders.

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).

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

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 resulting girder wind load needs only to be applied to the windward girder and the wind area shall be considered to be 1.6 times the projected area of the girder. The wind load on the trolley shall be considered as equally divided between the two girders, and the wind area shall be considered as 1.6 times the projected area of non-enclosed trolleys and 1.2 times the projected area of enclosed trolleys. 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.

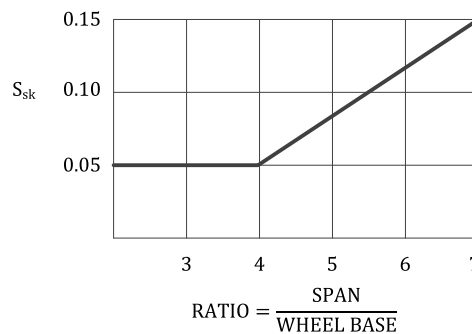
When the projected area of the lifted load is not specified by the purchaser/owner, the following area should be used, which includes consideration of a 1.2 shape factor, where RL is the crane's Rated Load in Tons:

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

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 (S_{sk})

When two wheels (or two bogies) 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 (or bogie) by coefficient S_{sk} which depends upon the ratio of the span to the wheel base.



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.

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

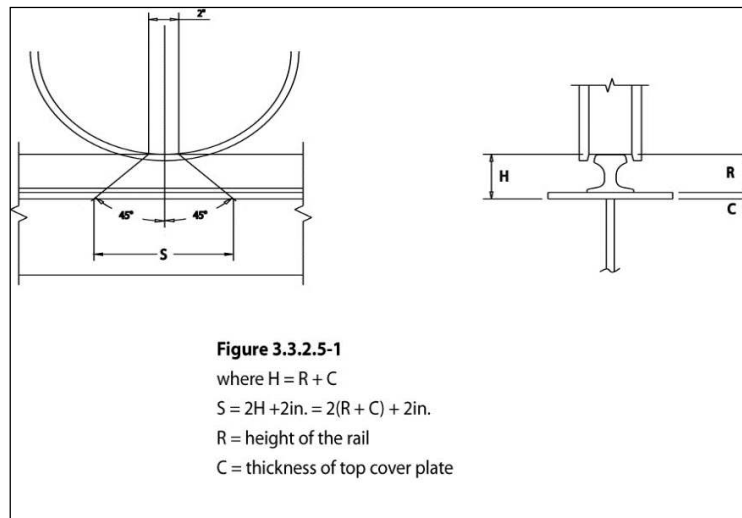
Torsional moment due to vertical forces acting eccentric to the vertical neutral axis of the girder shall be considered as those vertical forces multiplied by the horizontal distance between the centerline of the forces and the shear center of the girder.

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 Longitudinal Distribution of the Wheel Load

Local stresses in the rail, rail base, flanges, welds, and in the web plate due to wheel load acting normal and transversely to the rail shall be determined in accordance with the rail and flange system. The individual wheel load can be uniformly distributed in the direction of the rail over a length of $S = 2(R + C) + 2 \text{ in.}$, provided that the rail is directly supported on the flange as shown in Figure 3.3.2.5-1.



3.3.2.6 Load Combination

The combined stresses shall be calculated for the following design cases:

3.3.2.6.1 Case 1: Crane in regular use under principal loading

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

3.3.2.6.2 Case 2: Crane in regular use under principal and additional loading

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

3.3.2.6.3 Case 3: Extraordinary loads

3.3.2.6.3.1 Crane subjected to out of service wind

$$DL + TL + WLS$$

3.3.2.6.3.2 Crane in collision

$$DL + TL + LL + CF$$

3.3.2.6.3.3 Test Loads

CMAA recommends test load not to exceed 125 percent of rated load.

3.4 ALLOWABLE STRESSES

TABLE 3.4-1

	LOAD COMBINATION	ALLOWABLE COMPRESSION STRESS* σ_{CALL}	ALLOWABLE TENSION STRESS σ_{TALL}	ALLOWABLE SHEAR STRESS* τ_{ALL}	ALLOWABLE BEARING STRESS $\sigma_{Br gALL}$
3.4.1	Case 1	$0.60\sigma_{yp}$	$0.60\sigma_{yp}$	$0.36\sigma_{yp}$	$0.80\sigma_{yp}$
3.4.2	Case 2	$0.66\sigma_{yp}$	$0.66\sigma_{yp}$	$0.40\sigma_{yp}$	$0.90\sigma_{yp}$
3.4.3	Case 3	$0.75\sigma_{yp}$	$0.75\sigma_{yp}$	$0.45\sigma_{yp}$	$1.00\sigma_{yp}$

*For components subject to buckling, see Section [3.4.6](#) and [3.4.8](#)

3.4.4 Combined Stresses

When loading conditions of a component or weld produce both tensile and compressive stresses in two orthogonal directions, the stresses shall be combined per Sections [3.4.4.1](#), [3.4.4.2](#) or [3.4.4.3](#) as appropriate, and the resulting stress limited to the respective allowable stress. Note that standard sign conventions of stresses must be used.

3.4.4.1 Combined stresses within a component:

$$\sigma_{COMB} = \sqrt{(\sigma_x)^2 + (\sigma_y)^2 - \sigma_x\sigma_y + 3(\tau_{xy})^2} \leq \sigma_{TALL} \quad (\text{Ref. Table } \a href="#">3.4-1$$

3.4.4.2 Combined stresses within the base metal of a welded joint:

$$\sigma_{COMB} = 1/2 [\sigma_x + \sigma_y] \pm 1/2 \sqrt{(\sigma_x - \sigma_y)^2 + 4(\tau_{xy})^2} \leq \sigma_{TALL} \quad (\text{Ref. Table } \a href="#">3.4-1$$

3.4.4.3 Combined stresses within the weld metal:

$$\sigma_{COMB} = 1/2 [\sigma_x + \sigma_y] \pm 1/2 \sqrt{(\sigma_x - \sigma_y)^2 + 4(\tau_{xy})^2} \leq \sigma_{WeldALL} \quad (\text{Ref. Section } \a href="#">3.2$$

3.4.5 Buckling Analysis

Local buckling, lateral and torsional buckling of the web plate and local buckling of the rectangular plates forming part of the compression member, shall be made in accordance with a generally accepted theory of the strength of materials. (Ref. Section [3.4.8](#))

3.4.6 Compression Member

3.4.6.1 The average allowable compression stress on the cross section area of axially loaded compression members susceptible to buckling shall be calculated when KL/r (the largest effective slenderness ratio of any segment) is less than C_c :

$$\sigma_A = \frac{\left[1 - \frac{(KL/r)^2}{2(C_c)^2}\right] \sigma_{yp}}{\left[\frac{5}{3} + \frac{3(KL/r)}{8C_c} - \frac{(KL/r)^3}{8(C_c)^3}\right] N}$$

$$\text{Where: } C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}}$$

- 3.4.6.2 The average allowable compression stress on the cross section area of axially loaded compression members susceptible to buckling shall be calculated when KL/r (the largest effective slenderness ratio of any segment) exceeds C_c :

$$\sigma_A = \frac{12\pi^2 E}{23(KL/r)^2 N}$$

- 3.4.6.3 Members subjected to both axial compression and bending stresses shall be proportioned to satisfy the following requirements:

$$\frac{\sigma_a}{\sigma_A} + \frac{C_{mx}\sigma_{bx}}{\left[1 - \frac{\sigma_a}{\sigma_{ex}}\right]\sigma_{BX}} + \frac{C_{my}\sigma_{by}}{\left[1 - \frac{\sigma_a}{\sigma_{ey}}\right]\sigma_{BY}} \leq 1.0$$

when $\frac{\sigma_a}{\sigma_A} \leq 0.15$ the following formula may be used:

$$\frac{\sigma_a}{\sigma_A} + \frac{\sigma_{bx}}{\sigma_{BX}} + \frac{\sigma_{by}}{\sigma_{BY}} \leq 1.0$$

where:

- K = effective length factor
- L = unbraced length of compression member
- r = radius of gyration of member
- E = modulus of elasticity
- σ_{yp} = yield point
- σ_a = the computed axial stress
- σ_b = computed compressive bending stress at the point under consideration
- σ_A = axial stress that will be permitted if axial force alone existed
- σ_B = compressive bending stress that will be permitted if bending moment alone existed
- σ_{BK} = allowable compression stress from Section [3.4](#)

$$\sigma_e = \frac{12\pi^2 E}{23(KL/r)^2 N}$$

- N = 1.1 for Case 1
- N = 1.0 for Case 2
- N = 0.89 for Case 3

C_{mx} and C_{my} = a coefficient whose value is taken to be:

1. For compression members in frames subject to joint translation (sidesway),
 $C_m = 0.85$.
2. For restrained compression members in frames braced against joint translation and not subject to transverse loading between their supports in the plane of bending:

$$C_m = 0.6 - 0.4 \left[\frac{M_1}{M_2} \right] \quad ; \text{ but not less than } 0.4$$

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

3. For compression members in frames braced against joint translation in the plane of loading and subjected to transverse loading between their supports, the value of C_m may be determined by rational analysis. However, in lieu of such analysis, the following values may be used:
 - (a) For members whose ends are restrained $C_m = 0.85$
 - (b) For members whose ends are unrestrained $C_m = 1.0$

3.4.7 Allowable Stress Range - Repeated Load

Members and fasteners subject to repeated load shall be designed so that the maximum stress does not exceed that shown in Sections 3.4.1 thru 3.4.6, nor shall the stress range (maximum stress minus minimum stress) exceed allowable values for various categories as listed in Table 3.4.7-1. The minimum stress is considered to be negative if it is opposite in sign to the maximum stress. The categories are described in Table 3.4.7-2A with sketches shown in Figure 3.4.7-2B. The allowable stress range is to be based on the condition most nearly approximated by the description and sketch. See Figure 3.4.7-3 for typical box girders. See Figure 3.4.7-4 for typical bridge rail.

TABLE 3.4.7-1
ALLOWABLE STRESS RANGE (ksi)

CMAA SERVICE CLASS	JOINT CATEGORY					
	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
E	24	18	13	10	8	9
F	24	16	10	7	5	8

Stress range values are independent of material yield strength.

TABLE 3.4.7-2A**FATIGUE STRESS PROVISIONS - TENSION (T), REVERSAL (REV) OR SHEAR (S) STRESSES**

GENERAL CONDITION	SITUATION	JOINT CATEGORY	EXAMPLE OF A SITUATION	KIND OF STRESS
Plain Material	Base metal with rolled or cleaned surfaces. Oxygen-cut edges with ANSI smoothness of 1000 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 radiographic or ultrasonic inspection.	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 2.5 (40%) and weld soundness established by radiographic or ultrasonic inspection.	B	10,11	T or Rev.
	Weld metal of partial penetration transverse groove welds based on effective throat area of the weld or welds.	F	17	T or Rev.
	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 2.5 (40%) and when in either case reinforcement is not removed and weld soundness is established by radiographic or ultrasonic inspection.	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 2.5 (40%) with a permanent backing bar when the weld is ground roughly parallel to the direction of the stress and weld soundness is established by nondestructive testing. The backing bar is to be continuous and if spliced, is to be joined by a full penetration butt weld. The backing bar is to be connected to the parent metal by continuous welds along both edges. Intermittent welds may be used in regions of compression stress.			
	Welds parallel to direction of the stress:	B	19 & 20	T or Rev.
	Welds perpendicular to direction of the stress:			
	(a) $L \leq 2$ in.	C	19	T or Rev.
	(b) 2 in. $< L \leq 4$ in.	D	19	T or Rev.
	(c) $L > 4$ in.	E	19	T or Rev.
Groove Welded Connections	Base metal at details of any length attached by groove welds subjected to transverse or longitudinal loading, or both, when weld soundness transverse to the direction of stress is established by nondestructive testing and the detail embodies a transition radius, R, with the weld termination ground when:			
	Longitudinal Loading:			
	(a) $R \geq 24$ in.	B	13	T or Rev.
	(b) 24 in. $> R \geq 6$ in.	C	13	T or Rev.
	(c) 6 in. $> R \geq 2$ in.	D	13	T or Rev.
	(d) 2 in. $> R \geq 0$	E	12,13	T or Rev.

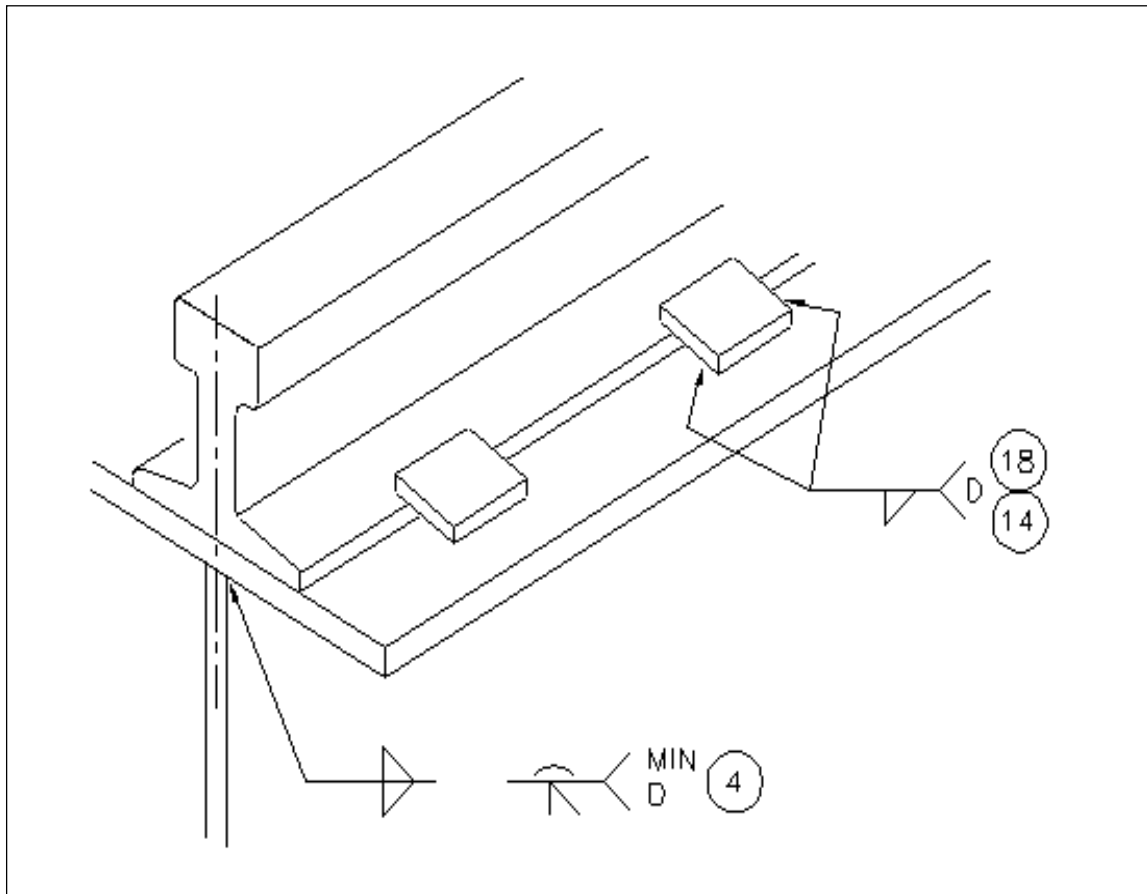
TABLE 3.4.7-2A (Continued)

GENERAL CONDITION	SITUATION	JOINT CATEGORY	EXAMPLE OF A SITUATION	KIND OF STRESS
Groove Welded Connections (continued)	Transverse Loading: Materials having equal or unequal thickness sloped, welds ground web connections excluded.			
	(a) $R \geq 24$ in.	B	13	T or Rev.
	(b) 24 in. $> R \geq 6$ in.	C	13	T or Rev.
	(c) 6 in. $> R \geq 2$ in.	D	13	T or Rev.
	(d) 2 in. $> R \geq 0$	E	12, 13	T or Rev.
	Transverse Loading:			
	Materials having equal thickness, not ground, web connections excluded.			
	(a) $R \geq 24$ in.	C	13	T or Rev.
	(b) 24 in. $> R \geq 6$ in.	C	13	T or Rev.
	(c) 6 in. $> R \geq 2$ in.	D	13	T or Rev.
	(d) 2 in. $> R \geq 0$	E	12, 13	T or Rev.
	Transverse Loading:			
	Materials having unequal thickness, not sloped or ground, including web connections			
	(a) $R \geq 24$ in.	E	13	T or Rev.
	(b) 24 in. $> R \geq 6$ in.	E	13	T or Rev.
	(c) 6 in. $> R \geq 2$ in.	E	13	T or Rev.
	(d) 2 in. $> R \geq 0$	E	12, 13	T or Rev.
Groove or fillet welded connections	Base metal at details attached by groove or fillet welds subject to longitudinal loading when the detail embodies a transition radius, R , less than 2 in., and when the detail length, L , parallel to the line of stress is			
	(a) $L \leq 2$ in.	C	12, 14, 15, 16, 18	T or Rev.
	(b) 2 in. $< L \leq 4$ in.	D	12, 18	T or Rev.
	(c) $L > 4$ 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.			
	(a) When $R \geq 24$ in.	B	13	T or Rev.
	(b) When 24 in. $> R > 6$ in.	C	13	T or Rev.
	(c) When 6 in. $\geq R > 2$	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 so as 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

TABLE 3.4.7-2A (Continued)

GENERAL CONDITION	SITUATION	JOINT CATEGORY	EXAMPLE OF A SITUATION	KIND OF STRESS
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 which 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
	Base metal at net section of high strength bolted bearing connections.	B	32, 33	T or Rev

**FIGURE 3.4.7-4
FOR TYPICAL BRIDGE RAIL**



3.4.8 Buckling

3.4.8.1 Local Buckling or Crippling of Flat Plates

The structural design of the crane must guard against local buckling and lateral torsional buckling of the web plates and cover plates of girder. For purposes of assessing buckling, the plates are subdivided into rectangular panels of length ' a ' and width ' b '. The length ' a ' of these panels corresponds to the center distance of the full depth diaphragms or transverse stiffeners welded to the panels.

In the case of compression flanges, the length ' b ' of the panel indicates the distance between web plates, or the distance between web plates and/or longitudinal stiffeners. In the case of web plates, the length of ' b ' of the panel indicates the depth of the girder, or the distance between compression or tension flanges and/or horizontal stiffeners.

3.4.8.2 Critical buckling stress shall be assumed to be a multiple of the Euler Stress σ_e

$$\sigma_k = K_\sigma \sigma_e; \quad \tau_k = K_\tau \sigma_e$$

where: K_σ = buckling coefficient compression

K_τ = buckling coefficient shear