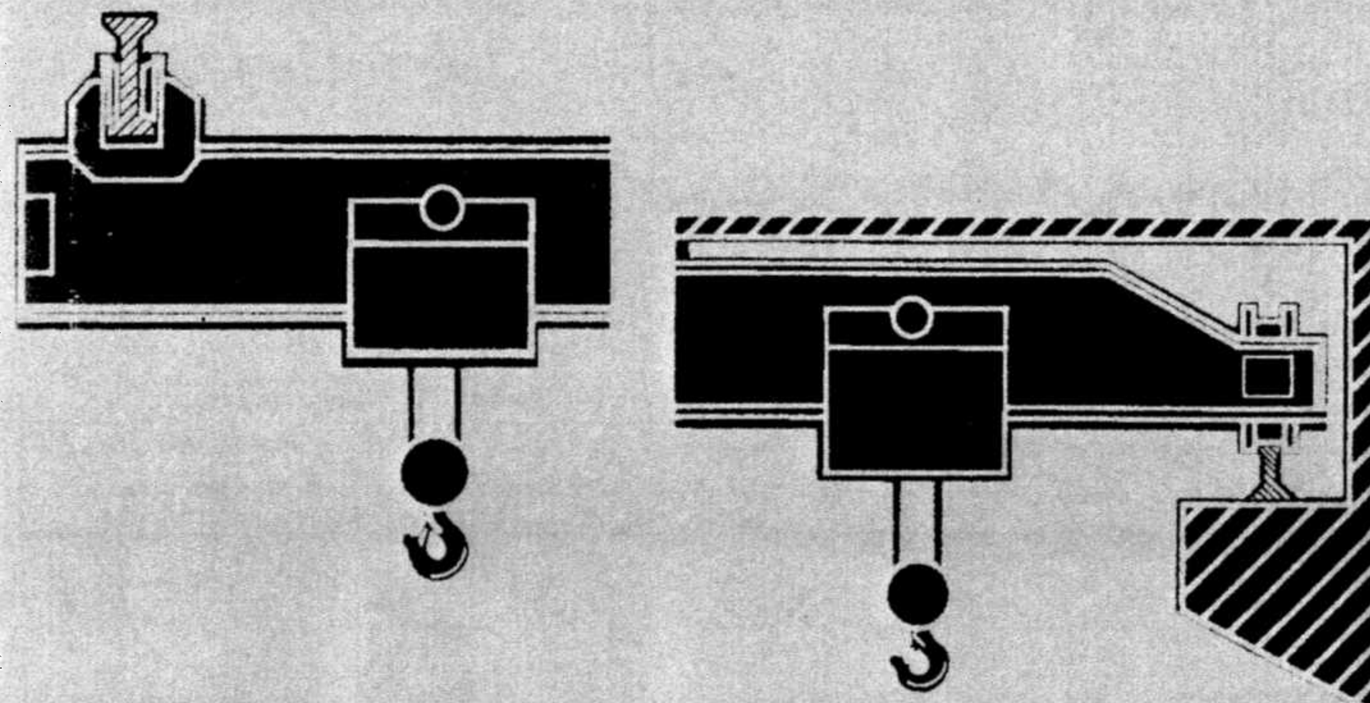
CMAA®
CRANE MANUFACTURERS
ASSOCIATION OF AMERICA, INC.

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 2004
Supersedes Specification #74, Revised 2000

MATERIAL HANDLING INDUSTRY OF AMERICA®

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CMAA SPECIFICATION NO. 74-2004
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 should 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, the items listed may be checked with individual manufacturers and comparisons made leading to optimum selection of equipment.

These Specifications consist of eight sections, as follows:

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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 2004.

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 Section 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, 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

AGMA — American Gear Manufacturers Association
1500 King Street, Suite 201
Alexandria, Virginia 22314-2730

2001-C95:	Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth
AGMA 908-B89:	Geometry Factors for Determining Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth
6010-F97:	Spur, Helical, Herringbone and Bevel Enclosed Drives

AISC — American Institute of Steel Construction
1 East Wacker, Suite 3100
Chicago, Illinois 60601-2001

ANSI — American National Standards Institute
11 West 42nd Street
New York, New York 10036

ASCE	The American Society of Civil Engineers 1801 Alexander Bell Drive Reston, Virginia 20191 ASCE 7-98 - Minimum Design Loads for Buildings and Other Structures
ASME	American Society of Mechanical Engineers 22 Law Drive, P.O. Box 2300 Fairfield, New Jersey 07007-2300 ASME B30.11-1998 - Monorails and Underhung Cranes ASME B30.16-1993 - Overhead Hoists (Underhung) ASME B30.17-1995 - Overhead and Gantry Cranes (Top Running, Single Girder, Underhung Hoist)
ASTM	American Society of Testing and Materials 100 Barr Harbor Drive West Conshocken, Pennsylvania 19428
AWS	American Welding Society 550 N.W. LeJeune Road, P.O. Box 351040 Miami, Florida 33126 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, North Carolina 28217-3992 Overhead Crane and Maintenance Checklist Crane Operator's Manual Crane Operator's Training Video
NEC NFPA	National Electric Code National Fire Protection Association 1 Batterymarch Park, P.O. Box 9101 Quincy, Massachusetts 02269-9101 1999 70-935B
NEMA	National Electrical Manufacturers Association 1300 North 17th Street, Suite 1847 Rosslyn, Virginia 22209 ICS1-1993 - Industrial Control Systems and Electrical Requirements
HMI	Hoist Manufacturers Institute 8720 Red Oak Blvd., Suite 201 Charlotte, North Carolina 28217-3992
OSHA	U.S. Department of Labor Directorate of Safety Standards Program 200 Constitution Avenue, N.W. Washington, DC 20210 29 CFR Part 1910 - Occupational Safety & Health Standards for General Industry (Revised 7/1/97)

Stress Concentration
R.E. Peterson / Walter D. Pilkey
Copyright, 1997
John Wiley & Sons, Inc.

Data was utilized from (FEM) Federation Europeenne De La Manutention, Section IX Series Lifting Equipment

Local Girder Stresses
FEM.9.341 1st Edition (E) 10.1983

1.1.7 The Hoist and Trolley may be supplied by the crane manufacturers or by the purchaser. In either case, the Hoist and Trolley shall comply with applicable Specifications of the Hoist Manufacturers Institute and with ASME B.30.16-1993 safety standard for "Overhead Hoists (Underhung)." If the Hoist and/or Trolley are supplied by the purchaser, the crane builder shall be provided with certified dimensional drawings with all required data, including wiring diagrams, trolley connector locations, and trolley hoist weight. This CMAA Specification #74 does not apply to the hoist and/or trolley.

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 obstructions.

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 accordance with ANSI A14.3, Safety Requirements for Fixed Ladders.

1.3 CLEARANCE

1.3.1 A minimum clearance of 3 inches between the highest point of the crane and the lowest overhead obstruction shall be provided. For buildings where truss sag becomes a factor, this clearance should be increased accordingly.

1.3.2 The clearance between the end of the crane and building columns, knee braces or any other obstruction shall not be less than 2 inches with crane centered on runway rails. Pipes, conduits, 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 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 and at the same elevation. The center to center distance, and the elevation shall be within the tolerances given in Table 1.4.1-1.

1.4.1.1.2 The runway rails should be standard rail sections or any other commercial rolled section with equivalent Specifications of a proper size for the crane to be installed.

1.4.1.1.3 Proper rail splices and hold down fasteners are to be provided. Rail separation at joints shall not exceed 1/16 inch. Floating rails are not recommended.

1.4.1.1.4 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

1.4.1.2 Under-Running Runways

1.4.1.2.1 Under-running runway beams shall be straight and parallel. The wheel running surface shall be at the same elevation, have no transverse tilt, and shall be held in alignment at joints.

1.4.1.2.2 The center to center distance and the elevation shall be within the tolerances given in Table 1.4.1-1. The maximum gap between ends of the load carrying flanges shall not exceed 1/16 inch.

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.

1.5 RUNWAY CONDUCTORS

1.5.1 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.

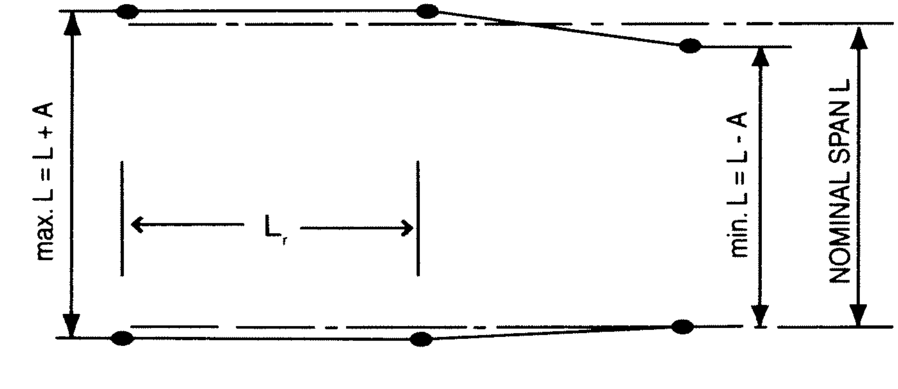
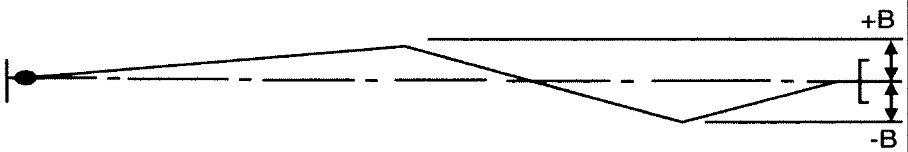
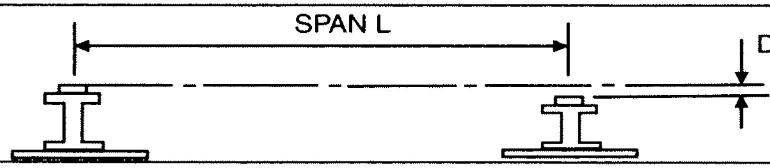
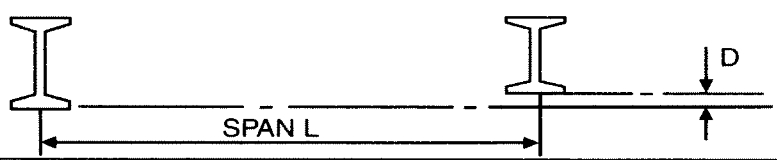
1.5.2 The runway conductors may be bare hard drawn copper wire, hard copper, aluminum or steel in the form of stiff shapes, insulated cables, cable reel pickup or other suitable means to meet the particular application and shall be installed in accordance with Article 610 of the National Electrical Code and comply with all local applicable codes.

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 Electric 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.

TABLE 1.4.1-1

ITEM	FIGURE	OVERALL TOLERANCE	MAXIMUM RATE OF CHANGE
CRANE SPAN (L) MEASURED AT CRANE WHEEL CONTACT SURFACE		L ≤ 50′ A = 3/16″ L > 50′ ≤ 100′ A = 1/4″ L > 100′ A = 3/8″	1/4″ IN 20′-0″
STRAIGHTNESS (B)		B = 3/8″	1/4″ IN 20′-0″
ELEVATION (C)		C = 3/8″	1/4″ IN 20′-0″
TOP RUNNING TRANSVERSE RAIL TO RAIL ELEVATION (D)		L ≤ 50′ D = ± 3/16″ L > 50 ≤ 100′ D = ± 1/4″ L > 100′ D = ± 3/8″	N/A
TRANSVERSE GIRDER TO GIRDER ELEVATION UNDER RUNNING (D)			

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.

1.6 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

Materials shall be properly selected for the stresses and work cycles to which they are subjected.

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.

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 ASME B30.11 (1988) Monorails and Underhung Cranes; ASME B30.16 (1993) Overhead Hoists (Underhung); and ASME B30.17 (1992) 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 manufacturers's plant according to the manufacturer's standard.

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

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, CMSC-Specification #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.

74-2 CRANE CLASSIFICATIONS

2.1 GENERAL

Service classes have been established so that the most economical crane for the installation may be specified in accordance with this Specification.

The crane service classification is based on the load spectrum reflecting the actual service conditions as closely as possible.

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 which can be expressed in terms of the mean effective load factor.

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

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)

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).

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 lift at rated capacity.

2.5 CLASS D (HEAVY SERVICE)

This service covers crane 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				k = 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		0.531 - 0.67
L_3	C	D			0.671 - 0.85
L_4	D				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

L_1= Cranes which hoist the rated load exceptionally and normally, very light loads.

L_2= Cranes which rarely hoist the rated load, and normal loads of about $^1/_3$ of the rated load.

L_3= Cranes which hoist the rated load fairly frequently and normally, loads between $^1/_3$ and $^2/_3$ of the rated load.

L_4= Cranes which are regularly loaded close to the rated load.

LOAD CYCLES

N_1= 20,000 to 100,000 cycles

N_2= 100,000 to 500,000 cycles

N_3= 500,000 to 2,000,000 cycles

N_4= Over 2,000,000 cycles

74-3 STRUCTURAL DESIGN

3.1 MATERIAL

All structural steel should conform to ASTM-A36 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 the current issue of 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 3.4.4.2, 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 3.3.2.5.2 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

The vertical inertia forces 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:

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

3.3.2.1.4.2 Hoist Load Factor (HLF)

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

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

3.3.2.1.5 Inertia Forces From Drives (IFD)

The inertia forces occur during acceleration or deceleration of crane motions and depend on the driving and braking torques applied by the drive units and brakes during each cycle.

The lateral load due to acceleration or deceleration shall be a percentage of the vertical load and shall be considered as 7.8 times the lateral acceleration or deceleration rate (FT/SEC^2) but not less than 2.5 percent of the vertical load. This percentage is to be applied to both the live and dead loads, exclusive of the end trucks. The live load shall be located in the same position as when calculating the vertical moment. The moment of inertia of the entire girder section about its vertical axis shall be used to determine the stresses due to lateral forces. The inertia forces during acceleration and deceleration shall be calculated in each case with the trolley in the worst position for the component being analyzed.

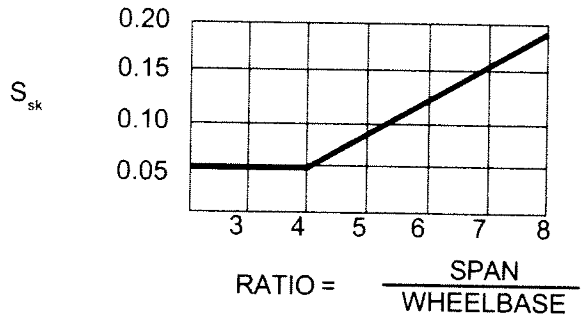
3.3.2.2 Additional Loads

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 of projected area exposed to the wind. Where multiple surfaces are exposed to the wind, and the horizontal distance between the surfaces is greater than the depth of the largest surface, the wind area shall be considered to be 1.6 times the projected area of the largest surface. For single surfaces, such as cabs or machinery enclosures, the wind area shall be considered to be 1.2 (or that applicable shape factor specified by ASCE 7-latest revision) times the projected area.

3.3.2.2.2 **Forces due to Skewing (SK)**

When wheels roll along a rail, the horizontal forces normal to the rail, and tending to skew the structure 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 7-latest revision 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:

$$E = \frac{M_1 M_2 (.4V_{T1} + .4V_{T2})^2}{2(M_1 + M_2)}$$

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 (Stress Level 1)

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

3.3.2.5.2 Case 2: Crane in regular use under principal and additional loading (Stress Level 2)

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

3.3.2.5.3 Case 3: Extraordinary Loads (Stress Level 3)

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

$DL + TL + LL + CF$

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:

$$\sigma_{x0} = C_{x0} \frac{P}{(t_a)^2} \qquad \sigma_{Y0} = C_{Y0} \frac{P}{(t_a)^2}$$

Underside of flange directly beneath wheel contact point —Point 1:

$$\sigma_{x1} = C_{x1} \frac{P}{(t_a)^2} \qquad \sigma_{Y1} = C_{Y1} \frac{P}{(t_a)^2}$$

Topside of flange at flange-to-web transition —Point 2:

$\sigma_{X2} = -\sigma_{X0}$ $\sigma_{Y2} = -\sigma_{Y0}$

For tapered flange sections (Figure 3.3.2.6-2)

$$C_{X0} = -1.096 + 1.095\lambda + 0.192e^{-6.0\lambda}$$

$$C_{X1} = 3.965 - 4.835\lambda - 3.965e^{-2.675\lambda}$$

$$C_{Y0} = -0.981 - 1.479\lambda + 1.120e^{1.322\lambda}$$

$$C_{Y1} = 1.810 - 1.150\lambda + 1.060e^{-7.70\lambda}$$

$$t_a = t_f - \left[\frac{b}{24}\right] + \left[\frac{a}{6}\right]$$ for standard "S" section

where: t_f = published flange thickness for standard "S" section (inches)

For parallel flange section (Figure 3.3.2.6-3 & 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)

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

b = section width across flanges (inches)

For other cases (Figure 3.3.2.6-4)

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

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

where: P = Load per wheel including HLF (pounds)

t_a = Flange thickness at point of load application (inches)

t_w = Web thickness (inches)

a = Distance from edge of flange to point of wheel load application (inches) (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 paragraph 3.3.2.5.2 of this Specification.

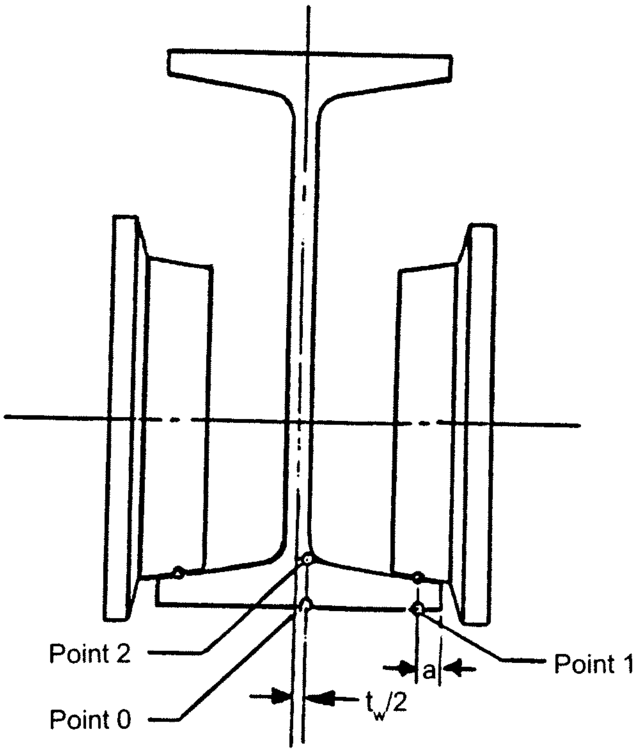


Figure 3.3.2.6-1

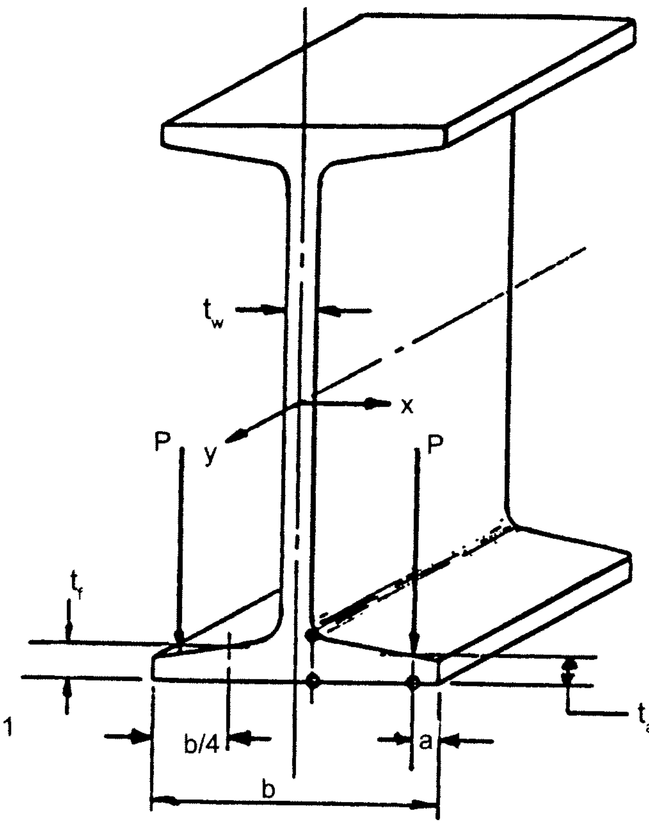


Figure 3.3.2.6-2

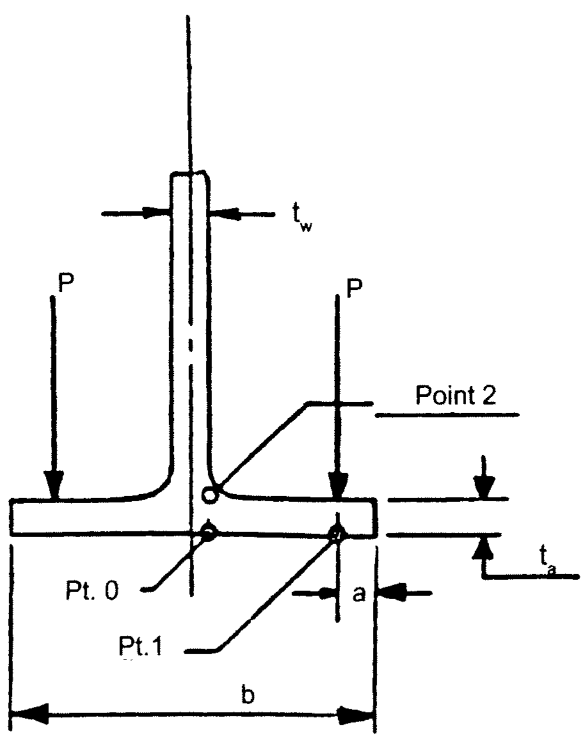
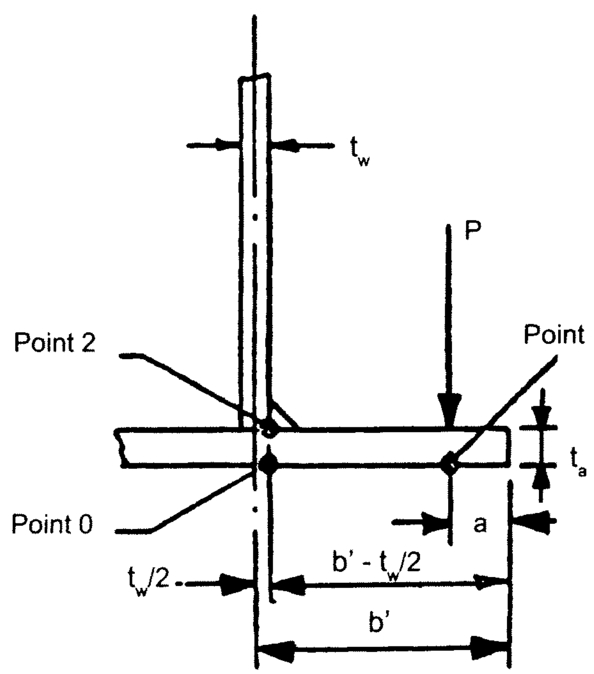


Figure 3.3.2.6-3



Lower Chord of a Box Girder
Figure 3.3.2.6-4

When calculating the combined stress, the flange bending stresses for single web girders are to be diminshed to 75% of the value calculated per paragraph 3.3.2.6.1.

The combined stress value (σ_t) obtained by the method prescribed in 3.4.4.1 shall not exceed the allowable Case 2 stress level of 0.66 σ_{yp}.

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 paragraph 3.3.2.5.2 of this Specification.

The combined stress value (σ_v) in the weld at Point 2 obtained by the method prescribed in paragraph 3.4.4.2 shall not exceed the allowable weld stress specified in paragraph 3.2 nor shall the stress range in the weld exceed the value specified in Table 3.4.7-1 for joint category E.

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 paragraphs 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.

3.4 ALLOWABLE STRESSES (σ_{ALL})

	STRESS LEVEL AND CASE	ALLOWABLE COMPRESSION STRESS*	ALLOWABLE TENSION STRESS	ALLOWABLE SHEAR STRESS	ALLOWABLE BEARING STRESS
3.4.1	1	$0.60\sigma_{yp}$	$0.60\sigma_{yp}$	$0.35\sigma_{yp}$	$0.75\sigma_{yp}$
3.4.2	2	$0.66\sigma_{yp}$	$0.66\sigma_{yp}$	$0.375\sigma_{yp}$	$0.80\sigma_{yp}$
3.4.3	3	$0.75\sigma_{yp}$	$0.75\sigma_{yp}$	$0.43\sigma_{yp}$	$0.90\sigma_{yp}$

*Not subject to buckling. See paragraph 3.4.6 and 3.4.8.

3.4.4 Combined Stresses

3.4.4.1 Where state of combined plane stresses exits, the reference stress σ_t can be calculated from the following formula:

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

where: σ_t = tensile stress

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

$$\sigma_v = \quad {}^1/_2\,[\sigma_x + \sigma_y] \pm {}^1/_2\sqrt{(\sigma_x - \sigma_y)^2 + 4(\tau_{xy})^2} \leq \sigma_{ALL}$$

where: σ_v = shear stress

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. (See 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:

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

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:

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

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

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 Case 1
N = 1.0 Case 2
N = 0.89 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:

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

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 frame 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 Fig. 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.

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

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 nondestructive testing.	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 2½ and weld soundness established by nondestructive testing.	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.
Groove Welds	Base metal and weld metal in or adjacent to complete joint penetration groove welded splices either not requiring transition or when required with transitions having slopes no greater than 1 to 2½ and when in either case reinforcement is not removed and weld soundness is established by nondestructive testing.	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 1/2 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 non-destructive 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.
	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.

TABLE 3.4.7-2A (Continued)

FATIGUE STRESS PROVISIONS - TENSION (T), REVERSAL (REV) OR SHEAR (S) STRESSES

GENERAL CONDITION	SITUATION	JOINT CATEGORY	EXAMPLE OF A SITUATION	KIND OF STRESS
	(c) 6 in. > R ≥ 2 in.	D	13	T or Rev.
	(d) 2 in. > R ≥ 0	E	12,13	T or Rev.
	Transverse Loading: Materials having equal thickness, not ground, web connections excluded.			
	(a) R ≥ 24 in.	C	13	T or Rev.
	(b) 24 in. > R ≥ 6 in.	C	13	T or Rev.
	(c) 6 in. > R ≥ 2 in.	D	13	T or Rev.
	(d) 2 in. > R ≥ 0	E	12,13	T or Rev.
	Transverse Loading: Materials having unequal thickness, not sloped or ground, including web connections			
	(a) R ≥ 24 in.	E	13	T or Rev.
	(b) 24 in. > R ≥ 6 in.	E	13	T or Rev.
	(c) 6 in. > R ≥ 2 in.	E	13	T or Rev.
	(d) 2 in. > R ≥ 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 where the details embodies a transition radius, R, less than 2 in., and when the detail length, L, parallel to the line of stress is			
	(a) L ≤ 2 in.	C	12,14,15, 16,18	T or Rev.
	(b) 2 in. < L ≤ 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 ≥ 24 in.	B	13	T or Rev.
	(b) When 24 in. > R > 6 in.	C	13	T or Rev.
	(c) When 6 in. ≥ R > 2	D	13	T or Rev.

GENERAL CONDITION	SITUATION	JOINT CATEGORY	EXAMPLE OF A SITUATION	KIND OF STRESS
Fillet welded connections	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.
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 3.4.7-2B

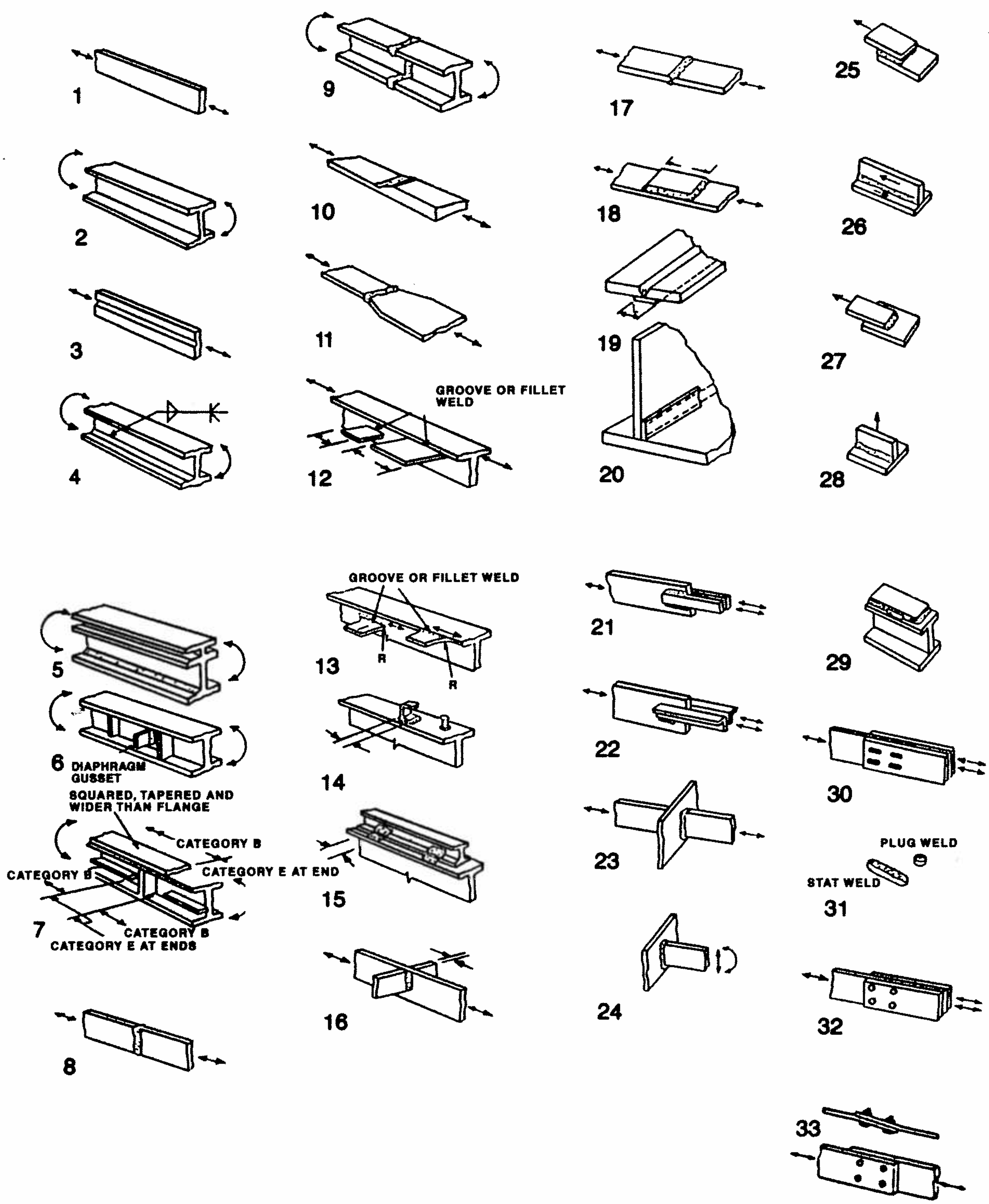
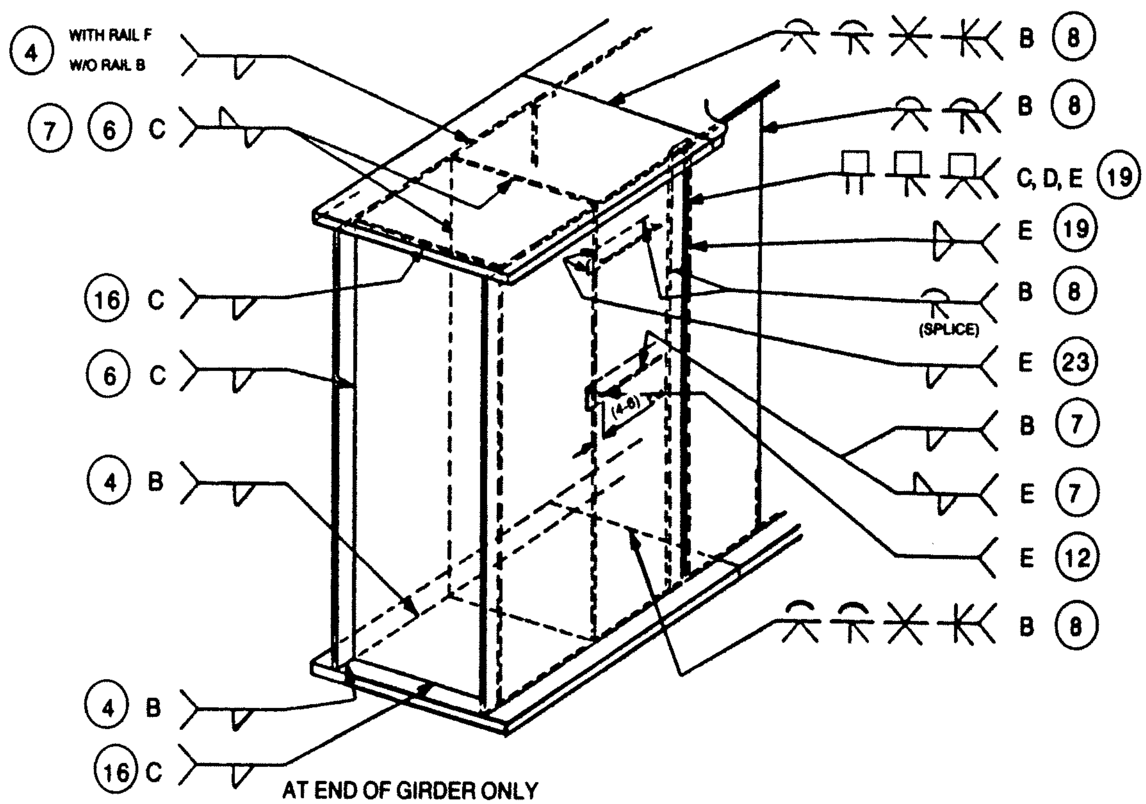


FIGURE NO. 3.4.7-3
FOR TYPICAL BOX GIRDER



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 the 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 "b" of the panel indicates the depth of the girder, or the distance between compression flanges 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.

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

where: K_σ = buckling coefficient compression

K_τ = buckling coefficient shear

The buckling coefficient K_σ and K_τ are identified for a few simple cases for plates with simply supported edges in Table 3.4.8.2-1 and depend on:

- ratio α = a/b of the two sides of the plate.
- manner in which the plate is supported along the edges
- type of loading sustained by the plate.

It is not the intention of this Specification to enter into further details of this problem. For a more detailed and complex analysis such as evaluation of elastically restrained edges, continuity of plate, and determination of the coefficient of restraint, reference should be made to specialized literature.

σ_e = Euler buckling stress which can be determined from the following formula:

$$\sigma_e = \frac{\pi^2 E}{12(1-\mu^2)} \left[\frac{t}{b}\right]^2 = [26.21 \times 10^6] \left[\frac{t}{b}\right]^2$$

where: E = modulus of elasticity (for steel E = 29,000,000 psi)

μ = Poisson's ratio (for steel μ = 0.3)

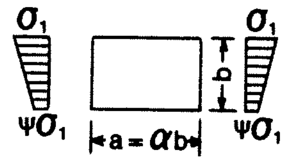
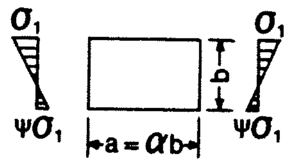
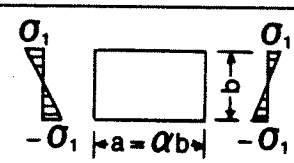
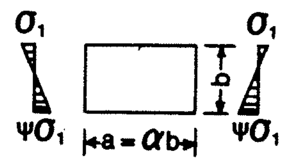
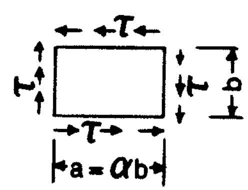
t = thickness of plate (inches)

b = width of plate (inches) perpendicular to the compression force.

If compression and shear stresses occur simultaneously, the individual critical buckling stresses σ_k and τ_k and the calculated stress values σ and τ are used to determine the critical comparison stress.

$$\sigma_{1k} = \frac{\sqrt{\sigma^2 + 3\tau^2}}{\left[\frac{1+\psi}{4}\right]\left[\frac{\sigma}{\sigma_k}\right] + \sqrt{\left[\frac{3-\psi}{4}\ \frac{\sigma}{\sigma_k}\right]^2 + \left[\frac{\tau}{\tau_k}\right]^2}}$$

TABLE NO. 3.4.8.2-1

Case	Loading		Buckling Stress	Range of Application	Buckling Coefficient
1	Compressive stresses, varying as a straight line. $0 \leqslant \Psi \leqslant 1$		$\sigma_k = K_\sigma \sigma_e$	$\alpha \geqslant 1$ $\alpha < 1$	$K_\sigma = \frac{8.4}{\Psi + 1.1}$ $K_\sigma = \left[\alpha + \frac{1}{\alpha}\right]^2 \left[\frac{2.1}{\Psi + 1.1}\right]$
2	Compressive and tensile stresses; varying as a straight line and with the compression predominating. $-1 < \Psi < 0$		$\sigma_k = K_\sigma \sigma_e$		$K_\sigma = [(1 + \Psi)K'] - (\Psi K'') + [10\Psi (1 + \Psi)]$ wherein K′ is the buckling coefficient for $\Psi = 0$ (case 1) and K″ is the buckling coefficient for $\Psi = -1$ (case 3).
3	Compressive and tensile stresses, varying as a straight line, with equal edge values, $\Psi = -1$ or with predominantly tensile stresses, $^*\Psi < -1$	 	$\sigma_k = K_\sigma \sigma_e$	$\alpha \geqslant 2/3$ $\alpha < 2/3$	$K_\sigma = 23.9$ $K_\sigma = 15.87 + \frac{1.87}{\alpha^2} + 8.6\alpha^2$
4	Uniformly distributed shear stresses. $\Psi = 1$		$\tau_k = K_\tau \sigma_e$	$\alpha \geqslant 1$ $\alpha < 1$	$K_\tau = 5.34 + \frac{4.00}{\alpha^2}$ $K_\tau = 4.00 + \frac{5.34}{\alpha^2}$

*For the calculation of α and σ_e in case 3 with predominant tension, replace dimension b by 2 × the width of the compression zone. But use actual b dimension to determine α and σ_e for the simultaneously acting shear stress portion.

where: σ = actual compression stress

τ = actual shear stress

σ_K = critical compression stress

τ_K = critical shear stress

ψ = stress ratio (see Table No. 3.4.8.2-1)

In the special case where $\tau = 0$ it is simply $\sigma_{1k} = \sigma_k$ and in the special case where $\sigma = 0$ then $\sigma_{1k} = \tau_k\sqrt{3}$

If the resulting critical stress is below the proportional limit, buckling is said to be elastic. If the resulting value is above the proportional limit, buckling is said to be inelastic. For inelastic buckling, the critical stress shall be reduced to:

$$\sigma_{1kR} = \frac{\sigma_{yp}\,(\sigma_{1k})^2}{0.1836\,(\sigma_{yp})^2 + (\sigma_{1k})^2}$$

where: σ_{yp} = yield point

σ_P = proportional limit (assumed at $\frac{\sigma_{yp}}{1.32}$)

3.4.8.3 Design Factors

The safety factor is ϑ_B calculated with the aid of the formulas:

In case of elastic buckling: $\vartheta_B = \dfrac{\sigma_{1k}}{\sqrt{\sigma^2 + 3\tau^2}} \geq DFB$

In case of inelastic buckling: $\vartheta_B = \dfrac{\sigma_{1kR}}{\sqrt{\sigma^2 + 3\tau^2}} \geq DFB$

The design factor DFB requirements of buckling are as follows:

TABLE 3.4.8.3-1

LOAD COMBINATION	DESIGN FACTOR DFB
Case 1	1.7 + 0.175 (ψ - 1)
Case 2	1.5 + 0.125 (ψ - 1)
Case 3	1.35 + 0.05 (ψ - 1)

3.5 DESIGN LIMITATIONS

3.5.1 Guideline for Proportions of Welded Box Girders:

Proportions:

L/h should not exceed 25
L/b should not exceed 65

b/t and h/t to be substantiated by buckling analysis.

where: L = span (inches)
b = distance between web plates (inches)
h = depth of girder (inches)
t = thickness of web plate (inches)

3.5.2 Longitudinal Stiffeners

3.5.2.1 When one longitudinal stiffener is used, it should be placed so that its centerline is approximately 0.4 times the distance from the inner surface of the compression flange plate to the neutral axis. It shall have a moment of inertia no less than:

$$I_0 = 1.2\left[0.4 + 0.6\left(\frac{a}{h}\right) + 0.9\left(\frac{a}{h}\right)^2 + 8\frac{A_s a}{h^2 t}\right] ht^3$$

If σ_c is greater than σ_τ a distance equal to twice the distance from the inner surface of the compression flange to the neutral axis shall be substituted in place of "h" in equation for I_0.

3.5.2.2 When two longitudinal stiffeners are used, they should be placed so that their centerlines are approximately 0.25 and 0.55 times the distance, respectively, from the inner surface of the compression flange plate to the neutral axis. They shall each have a moment of inertia no less than:

$$I_0 = 1.2\left[0.3 + 0.4\left(\frac{a}{h}\right) + 1.3\left(\frac{a}{h}\right)^2 + 14\frac{A_s a}{h^2 t}\right] ht^3$$

If σ_c is greater than σ_τ a distance equal to twice the distance from the inner surface of the compression flange to the neutral axis shall be substituted in place of "h" in equation for I_0.

where: a = longitudinal distance between full depth diaphragms or transverse stiffeners (inches)
A_s = area of one longitudinal stiffener (in^2)
I_0 = moment of inertia (in^4)

3.5.2.3 The moment of inertia of longitudinal stiffeners welded to one side of a plate shall be calculated about the interface of the plate adjacent to the stiffener. For elements of the stiffeners supported along one edge, the maximum width to thickness ratio shall not be greater than 12.7, and for elements supported along both edges, the maximum width to thickness ratio shall not be greater than 42.2. If the ratio of 12.7 is exceeded for the element of the stiffener supported along one edge, but a portion of the stiffener element conforms to the maximum width-thickness ratio and meets the stress requirements with the excess considered as removed, the member is considered acceptable.

3.5.3 Stiffened Plates in Compression

3.5.3.1 When one, two or three longitudinal stiffeners are added to a plate under uniform compression, dividing it into segments having equal unsupported widths, full edge support will be provided by the longitudinal stiffeners, and the provisions of Section 3.5.2.3 may be applied to the design of the plate material when stiffeners meet minimum requirements as follows:

3.5.3.1.1 For one longitudinal stiffener at the center of the compression plate, where b/2 is the unsupported half width between web and stiffener, the moment of inertia of the stiffener shall be no less than:

$$I_0 = \left[0.6\,\frac{a}{b} + 0.2\left(\frac{a}{b}\right)^2 + 3\left(\frac{A_s a}{b^2 t}\right)\right] bt^3$$

The moment of inertia need not be greater in any case than as given by the following equation:

$$I_0 = \left[2.2 + 10.3\,\frac{A_s}{bt}\left(1 + \frac{A_s}{bt}\right)\right] bt^3$$

3.5.3.1.2 For two longitudinal stiffeners at the third points of the compression flange, where b/3 is the unsupported width, and A the area of one stiffener, the moment of inertia of each of the two stiffeners shall be no less than:

$$I_0 = \left[0.4\,\frac{a}{b} + 0.8\left(\frac{a}{b}\right)^2 + 8\,\frac{A_s a}{b^2 t}\right] bt^3$$

The moment of inertia need not be greater in any case than:

$$I_0 = \left[9 + 56\left(\frac{A_s}{bt}\right) + 90\left(\frac{A_s}{bt}\right)^2\right] bt^3$$

3.5.3.1.3 For three longitudinal stiffeners, spaced equidistant at the one fourth width locations where b/4 is the unsupported width, and limited to a/b<3, the moment of inertia of each of the three stiffeners shall be no less than:

$$I_0 = \left[0.35\,\frac{a}{b} + 1.10\left(\frac{a}{b}\right)^2 + 12\,\frac{A_s a}{b^2 t}\right] bt^3$$

where: a = longitudinal distance between diaphragms or transverse stiffeners (inches)
A_s = area of the stiffener (in^2)
t = thickness of the stiffened plate (inches)
I_0 = moment of inertia (in^4)

Stiffeners shall be designed to the provisions of Section 3.5.2.3.

3.5.4 Diaphragms and Vertical Stiffeners

3.5.4.1 The spacing of the vertical web stiffeners in inches shall not exceed the amount given by the formula:

$$a = \frac{350\,t}{\sqrt{\tau_v}}$$

where: a = longitudinal distance between diaphragms or transverse stiffeners (inches)
t = thickness of web (inches)
τ_v = shear stress in web plates (ksi)

Nor should the spacing exceed 72 inches or h, the depth of the web, whichever is greater.

3.5.4.2 Full depth diaphragms may be included as vertical web stiffeners toward meeting this requirement.

3.5.4.3 The moment of inertia of any transverse stiffener about the interface of the web plate, if used in the absence of diaphragms, shall be no less than:

$$I = \frac{1.2\, h^3 (t_o)^3}{(a_o)^2}$$

where: a_o = required distance between stiffeners (inches)
t_o = minimum required web thickness (inches)
I = moment of inertia (in^4)

This moment of inertia does not include additional requirements, if any, for local moments. Stiffener elements shall be proportioned to the provisions of Section 3.5.2.3.

3.5.4.4 Web plates shall be suitable reinforced with full depth diaphragms or stiffeners at all major load points.

3.5.5 Deflection and Camber

3.5.5.1 The maximum vertical deflection of uncambered girders produced by the dead load, the weight of hoist, trolley and the rated load shall not exceed 1/600 of the span. Vertical inertia forces shall not be considered in determining deflection.

3.5.5.2 The maximum vertical deflection of cambered girders produced by the weight of the hoist, trolley and the rated load shall not exceed 1/888 of the span. Vertical inertia forces shall not be considered in determining deflection.

3.5.5.3 Box girders and single web girders should be cambered an amount equal to the dead load deflection plus one-half of the live load deflection.

3.5.6 Single Web Girders

Single web girders include wide flange beams, standard I beams, beams reinforced with plates, or other structural configurations having a single web. Where necessary, an auxiliary girder or other suitable means should be provided to support overhanging loads to prevent undue torsional and lateral deflections.

The maximum stresses with combined loading for Case 1 shall not exceed:

$$\text{Tension (ksi)} = 0.6\,\sigma_{yp}$$

$$\text{Compression (ksi)} = \frac{12{,}000}{\dfrac{Ld}{A_f}} \quad \text{with maximum of } 0.6\,\sigma_{yp}$$

where: L = span (unbraced length of top flange) (inches)
A_f = area of compression flange (in^2)
d = depth of beam (inches)

$$\text{Shear} = 0.35\,\sigma_{yp}$$

For cases 2 and 3, proportion stresses in accordance with Sections 3.4.1, 2, and 3.

3.5.7 Box Section Girder Built of Two Beams

Box section girder built up of two beams, either with or without reinforcing flange plates, shall be designed according to the same design data as for box section girder cranes for stress and deflection values only.

3.6 BRIDGE END TRUCK

3.6.1 The crane bridge shall be carried on end trucks designed to carry the rated load when lifted at one end of the crane bridge. The wheel base of the end truck shall be 1/8 of the span or greater.

3.6.2 End trucks may be of the rotating axle or fixed axle type as specified by the crane manufacturer.

3.6.3 The bridge end trucks should be constructed of structural steel or other suitable material. Provision shall be made to prevent the end truck from dropping more than one inch in case of axle failure. Rail sweeps shall be provided in front of each outside wheel and shall project below the top of the runway rail.

3.6.4 Load combinations and basic allowable stresses are to be in accordance with Sections 3.3.2.5 and 3.4.

3.6.5 When appropriate, equalizer bridge trucks are to be incorporated to promote sharing of bridge wheel loads. Equalizing pins are to be provided between equalizer truck and equalizer beams and/or rigid bridge structures.

3.7 OPERATOR'S CAB

3.7.1 The standard location of the operator's cab is at one end of the crane bridge unless otherwise specified. It shall be so located as not to interfere with the hook approach. The operator's cab shall be open type for indoor service unless otherwise specified. The cab shall be adequately braced to prevent swaying or vibration, but not so as to interfere with access to the cab or the vision of the operator. All bolts for supporting member connections should be in shear. Cab shall be provided with an audible warning device and fire extinguisher.

3.7.2 Provisions shall be made in the operator's cab for placement of the necessary equipment, wiring and fittings. All cabs should be provided with a seat unless otherwise specified.

3.7.3 For allowable stresses, use stress level 2, Section 3.4.2.

3.7.4 The controllers or their operating handles are located as shown in Section 5.7.3 for the cab location, unless otherwise specified.

3.7.5 The means of access and egress to the cab should conform to ASME Standards B30.17.

3.8 STRUCTURAL BOLTING

3.8.1 Joints designed as high strength bolted connections are to conform to requirements of the "Specifications for Structural Joints Using ASTM A325 or A490 Bolts," as published by AISC, for load combination, Case 1, Section 3.3.2.5.1. Zinc causes stress corrosion in A490 and should not be used.

3.8.2 Finished and unfinished bolts, ASTM A307, are to be used at values of 90 percent of those tabulated in Part 4 of the current issue of the AISC Manual of Steel Construction for load combination, Case 1, Section 3.3.2.5.1.

3.8.3 Allowable bolt stresses for load combination Cases 2 and 3, Sections 3.3.2.5.2 and 3, are to be proportioned in accordance with Sections 3.4.1, 2 and 3.

4.1 BRIDGE DRIVES

4.1.1 The bridge drive will consist of motor or motors driving through a suitable reduction unit or units to the wheels located at each end of the bridge.

4.1.1.1 When called for on the information sheets, a cushioned drive may be provided for starting the bridge.

4.2 GEARING

4.2.1 The types of gearing shall be specified by the crane manufacturer. When worm gearing is used for travel drives, consideration should be given to its backdriving characteristics.

4.2.2 All gears and pinions shall be constructed of material of adequate strength and durability to meet the requirements for the intended class of service, and manufactured to American Gear Manufacturers Association (AGMA) quality class 5 or better.

For the purpose of this Specification, hoist gearing strength and durability shall be based on the horsepower required to lift the rated load. Travel gearing strength and durability shall be based on the motor name plate rating. Due consideration shall be given to the maximum brake torque which can be applied to the drive. Also, consideration shall be given to the fact that gearing for travel drives transmit a larger portion of the available motor torque than gearing for hoist drives.

4.2.3 The horsepower rating for all spur and helical gearing shall be based upon AGMA Standard 2001-C95 (Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth). For the purpose of this Specification, the horsepower formula may be written:

ALLOWABLE STRENGTH HORSEPOWER—

$$P_{at} = \left[\frac{N_p d}{126000\, K_v}\right]\left[\frac{F\, S_{at}\, J}{K_m P_d S_{fs} K_B}\right]$$

ALLOWABLE DURABILITY HORSEPOWER—

$$P_{ac} = \left[\frac{N_p F\, I}{126000\, K_v K_m S_{fd}}\right]\left[\frac{S_{ac}\, d\, C_h}{C_p}\right]^2$$

where:
- P_{at} = allowable strength horsepower
- P_{ac} = allowable durability horsepower
- N_p = pinion speed (rpm)
- d = pitch diameter of pinion (inches)
- K_v = dynamic factor (strength and durability)
- F = net face width of the narrowest of the mating gears
- K_m = load distribution factor (strength and durability)
- C_p = elastic coefficient
- C_h = hardness factor (durability)
- J = geometry factor (strength)
- I = geometry factor (durability)
- P_d = diametral pitch
- K_B = rim thickness factor
- S_{at} = allowable bending stress for material (psi) (strength)
- S_{ac} = allowable contact stress for material (psi) (durability)
- S_{fs} = crane class factor (strength)
- S_{fd} = crane class factor (durability)

Values for K_v, K_m, C_p, C_h, J, I, K_B, S_{ac} and S_{at} can be determined from the tables and curves in AGMA Standard 2001-C95. Crane class factor S_{fs} is tabulated in Table 4.2.3-2 and S_{fd} shall be the product of the machinery service factor (C_d) and the load factor (K_w), [$S_{fd} = C_d \times K_w$]. For C_d, refer to Table 4.2.3-1 and for K_w, refer to the equation below. The remaining values pertain to gear size and speed.

$$K_w = \frac{2\,(\text{Maximum load}) + (\text{Minimum load})}{3\,(\text{Maximum load})}$$

TABLE 4.2.3-1
MACHINERY SERVICE FACTORS

Crane Class	C_d
A	.64
B	.72
C	.80
D	.90

These factors are not to be used in sizing any commercial gearboxes. All commercial gearboxes are to be sized according to gearbox manufacturer's recommendations.

TABLE 4.2.3-2
CRANE CLASS FACTORS FOR STRENGTH HORSEPOWER RATING

Crane Class	S_{fs}
A	.75
B	.85
C	.90
D	.95

4.2.4 Means shall be provided to insure adequate and proper lubrication on all gearing.

4.2.5 All gearing not enclosed in gear cases which may constitute a hazard under normal operating conditions shall be guarded with provision for lubrication and inspection.

4.2.5.1 Guards shall be securely fastened.

4.2.5.2 Each guard shall be capable of supporting the weight of a 200 pound person without permanent distortion, unless the guard is located where it is impossible to step on.

4.3 BEARINGS

4.3.1 The type of bearing shall be specified by the crane manufacturer.

4.3.2 Anti-friction bearings shall be selected to give a minimum life expectancy based on full rated speed as follows:

TABLE 4.3.2-1
AFBMA L_{10} BEARING LIFE

Class A	1250 Hours
Class B	2500 Hours
Class C	5000 Hours
Class D	10000 Hours

Use K_w load factor for all applications.

Due consideration shall be given to the selection of the bearing in the event a crane is used for a limited time at an increased service class such as:

EXAMPLE - 'during a construction phase'

4.3.3 Sleeve bearing shall have a minimum allowable unit bearing pressure as recommended by the bearing manufacturer.

4.3.4 All bearings shall be provided with proper lubrication. Bearing enclosures should be designed as far as practicable to exclude dirt and prevent leakage of oil or grease.

4.4 BRIDGE BRAKES

4.4.1 A bridge brake or non-freecoasting mechanical drive shall be provided capable of stopping the motion of the bridge within a distance in feet equal to 10% of the full load speed in feet per minute when traveling at full speed with a full load.

4.4.2 Bridge brakes when provided, shall have the thermal capacity for the frequency of operation required by the service.

4.4.3 If a parking brake is provided, it should have a torque rating of at least 50% of the rated motor torque.

4.4.3.1 If parking brakes are provided they shall not prohibit the use of a drift point in the control circuit.

4.5 SHAFTS

4.5.1 All shafts, except the bridge cross-shaft sections which do not carry gears, should be cold rolled shafting quality or better. The shaft diameter and method of support shall be as specified by the crane manufacturer.

The bearing spacing for rotating shafts less than 400 rpm shall not exceed that calculated per:

$$L = \sqrt[3]{432{,}000\ D^2}$$

where: L = Distance between bearing centers (inches)
D = Shaft diameter (inches)

When the shaft speed exceeds 400 rpm, the bearing spacing shall not exceed that determined by the following formula, or the preceding formula whichever is less in order to avoid objectionable vibration at critical shaft speeds:

$$L = \sqrt{\frac{4{,}760{,}000\ D}{1.2N}}$$

where: L = Distance between bearing centers (inches)
D = Shaft diameter (inches)
N = Maximum shaft speed (rpm)

4.5.2 The torsional deflection of the bridge cross shaft shall not exceed 0.10 degrees/foot when 50% full load bridge drive rated motor torque, increased by any gear reduction between the motor and the shaft, is applied. In addition, this applied torque shall result in a bridge drive wheel movement no greater than 1% of the wheel circumference or 1/2 inch, whichever is less.

4.5.3 Stress Calculations

All shafting shall be designed to meet the stresses encountered in actual operation. Due consideration shall be given to the maximum brake torque which may be applied to this shaft. When significant stresses are produced by other forces, these forces shall be positioned to provide the maximum stresses at the section under consideration. Impact shall not be included.

4.5.3.1 Static Stress Check for Normal Operating Conditions

A. For shafting subjected to axial loads, the stress shall be calculated as follows— (for shafting not limited by buckling).

$$\sigma_D = \frac{P}{A}$$

where: P = total axial load (pounds)
A = cross sectional area of shaft (in^2)

This axial stress shall not exceed $\frac{\sigma_u}{5}$

B. For shafting loaded in bending, the stress shall be calculated as follows:

$$\sigma_B = \frac{Mr}{I}$$

where: M = bending moment at point of examination (inch pounds)
r = outside radius of shaft at point of examination (inches)
I = bending moment of inertia at point of examination+∞in^4)

This bending stress shall not exceed $\frac{\sigma_u}{5}$

C. For shafting load in torque, the shear stress shall be calculated as follows:

$$\tau_T = \frac{Tr}{J}$$

where: T = torque at point of examination (inch pounds)
r = outside radius of shaft at point of examination (inches)
J = polar moment of inertia of shaft at point of examination (in^4)

This shear stress shall not exceed $\frac{\sigma_u}{5\sqrt{3}}$

D. Transverse shear stress in shafting shall be calculated as follows:

For solid shafts:

$$\tau_V = \frac{1.33V}{A}$$

For hollow shafts:

$$\tau_V = \frac{2V}{A}$$

where: V = shear load at point of examination (pounds)
A = cross sectional area at point of examination (in^2)

These shear stresses shall not exceed $\frac{\sigma_u}{5\sqrt{3}}$

E. When combinations of stresses are present on the same element, they should be combined as follows:

Axial and bending stresses

$$\sigma_\Sigma = \sigma_D + \sigma_B$$

and shall not exceed $\frac{\sigma_u}{5}$

Shear stresses:

$$\tau_{\Sigma} = \tau_T + \tau_v$$

and shall not exceed $\dfrac{\sigma_u}{5\sqrt{3}}$

Axial and bending with torsional shear:

$$\sigma_{COMB} = \sqrt{(\sigma_{\Sigma})^2 + 3\,(\tau_T)^2}$$

This stress shall not exceed $\dfrac{\sigma_u}{5}$

Note: For simply loaded shafting, bending and torsional stresses are maximum on the outer fibers of the shaft and must be combined. The transverse shear stresses are maximum on the neutral axis of the shaft and combine with the torsional stresses but not with the bending stresses.

4.5.3.2 Fatigue Stress Check for Normal Operating Conditions

Any shafting subjected to fluctuating stresses such as the bending in rotating shafts or the torsion in reversing drives must be checked for fatigue. This check is an addition to Section 4.5.3.1 and need only be performed at points of geometric discontinuity where stress concentrations exist, such as fillets, holes, keys, press fits, etc. Pure stresses, i.e., (not combined) are to be calculated as in Section 4.5.3.1 except multiplied by the appropriate stress amplification factor. The allowable stresses are as follows:

a. Direct axial and bending: $\sigma_{F\Sigma} = K_{TD}\,\sigma_D + K_{TB}\,\sigma_B \le \dfrac{\sigma_e}{K_c}$

b. Torsional and transverse shear: $\tau_{F\Sigma} = K_{ST}\,\tau_T + K_{SV}\,\tau_V \le \dfrac{\sigma_e}{K_c\sqrt{3}}$

c. For combined stresses when all of the direct axial and bending stresses are combined with the torsional stresses and all are fluctuating:

$$\sigma_{FCOMB} = \sqrt{(\sigma_{F\Sigma})^2 + 3\,(K_{ST}\tau_T)^2} \le \frac{\sigma_e}{K_c}$$

d. For combined tensile and shear stresses when only part of these stresses are fluctuating:

$$\sigma_{FCOMB} = \sqrt{\left[\sigma_{av}\left(\frac{\sigma_e}{\sigma_{yp}}\right) + K_T\sigma_R\right]^2 + 3\left[\tau_{av}\left(\frac{\sigma_e}{\sigma_{yP}}\right) K_S\tau_R\right]^2} \le \frac{\sigma_e}{K_c}$$

where:

σ_e = endurance strength of shaft material = 0.36 $\sigma_{um}\,K_{SC}$
σ_u = average tensile strength of shaft material
σ_{um} = minimum tensile strength of shaft material
σ_{yp} = minimum yield strength of shaft material
σ_{av} = that part of the bending stress not due to fluctuating loads
τ_{av} = that part of the shear stress not due to fluctuating loads
σ_R = that part of the bending stress due to fluctuating loads
τ_R = that part of the shear stress due to fluctuating loads
K_{TB} = that stress amplification factor for bending
K_{TD} = stress amplification factor for direct tension
K_{ST} = stress amplification factor for torsional shear
K_{SV} = stress amplification factor for transverse shear
K_c = crane class factor
K_{SC} = surface condition factor

TABLE 4.5.3.2-1

K_{SC}	SURFACE CONDITION FACTOR
1.4	For Polished-Heat treated and inspected shafting
1.0	For Machined-Heat treated and inspected shafting
0.75	For Machined-General usage shafting

TABLE 4.5.3.2-2

CRANE CLASS	CRANE CLASS FACTOR K_C
A	1.0
B	1.015
C	1.03
D	1.06

4.5.4 Shafting in bearing must be checked for operating conditions. The bearing stress is calculated by dividing the radial load by the projected area, i.e. P/(d x L), where d is the shaft diameter and L is the length in bearing. This bearing stress must not exceed 50 percent of the minimum yield for non-rotating shafting.

This bearing stress must not exceed 20 percent of the minimum yield for oscillating shafting when not limited by the bushing material.

4.6 COUPLINGS

4.6.1 Cross shaft couplings other than flexible type, shall be steel or minimum ASTM A48, latest edition, Class 40 cast iron or equal material.

The type of coupling (other than flexible) may be compression, sleeve or flanged type. Flexible couplings shall be the crane manufacturers standard type.

4.6.2 Motor couplings shall be the crane manufacturers standard type.

4.7 WHEELS

4.7.1 Top Running Bridge Wheels

4.7.1.1 Unless other means of restricting lateral movement are provided, wheels shall be double flanged with treads accurately machined. Bridge wheels may have either straight treads or tapered treads assembled with the large diameter towards the center of the span. Drive wheels shall be machined in pairs within 0.001 inches per inch of diameter with a maximum of 0.010 inches on the diameter, whichever case is smaller. When flangeless wheel and side roller assemblies are provided, they shall be of a type and design recommended by the crane manufacturer.

4.7.1.2 Wheels shall be constructed of suitable material. Wheels shall be heat treated only if specified. Due consideration shall be given to the brittleness and impact strength of the material used.

4.7.1.3 Sizing of Wheels and Rails

Wheels shall be designed to carry the maximum wheel load under normal conditions without undue wear. The maximum wheel load is that wheel load produced with trolley handling the rated load in the position to produce the maximum reaction at the wheel, not including VIF. When sizing wheels and rails, the following parameters shall be considered:

wheel diameter = D (inches)
effective rail head width = W (inches)
hardness coefficient of the wheel = K
where: K = BHN x 5 (for wheels with BHN $\leq$ 260)
K = $1300\ (\text{BHN}/260)^{.33}$ (for wheels with BHN > 260)

The basic bridge and trolley recommended durability wheel loading for different wheel hardnesses and sizes in combination with different rail sizes are shown in Table 4.7.1-4. The values in the table are established by the product of D x W x K. In addition, the load factor, K_{wbw}, the speed factor C_s, and the crane service class shall be considered.

$$K_{wbw} = \frac{.75(BW) + f(LL) + .5(TW) - .5f(TW)}{.75(BW) + 1.5f(LL)}$$

where: BW = bridge weight; TW = trolley weight; LL = trolley weight + rated load; f = X/span

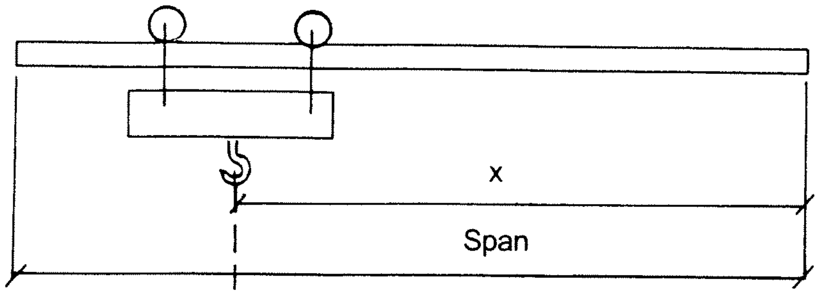


TABLE 4.7.1-1
TYPICAL BRIDGE LOAD FACTORS K_{wbw}

BRIDGE SPAN FT.	CAPACITY IN TONS							
	3	5	$7^1/_2$	10	15	20	25	30
20	.812	.782	.762	.747	.732	.722	.716	.716
30	.817	.785	.767	.750	.736	.725	.718	.718
40	.827	.794	.777	.760	.744	.732	.723	.723
50	.842	.809	.791	.771	.758	.740	.738	.731
60	.861	.830	.807	.790	.773	.754	.747	.741
70	.877	.844	.825	.807	.789	.768	.760	.752
80	.888	.857	.835	.818	.802	.779	.770	.761

4.7.1.4 The speed factor C_s depends on the rotational speed of the wheel and is listed in Table 4.7.1-2. These factors are obtained from the following formulas:

for RPM ≤ 31.5 $$C_s = \left[1 + \left(\frac{RPM - 31.5}{360}\right)\right]^2$$

for RPM > 31.5 $$C_s = 1 + \left(\frac{RPM - 31.5}{328.5}\right)$$

TABLE 4.7.1-2
SPEED FACTOR C_s

WHEEL DIA. IN INCHES	SPEED IN FEET PER MINUTE								
	30	50	75	100	125	150	175	200	250
5	.952	1.020	1.078	1.136	1.194	1.252	1.310	1.368	1.485
6	.932	1.001	1.049	1.098	1.146	1.194	1.243	1.291	1.388
8	.907	.958	1.013	1.049	1.086	1.122	1.158	1.195	1.267
9	.898	.944	1.001	1.033	1.066	1.098	1.130	1.163	1.227
10	.892	.932	.984	1.020	1.049	1.079	1.108	1.137	1.195
12	.882	.915	.958	1.001	1.025	1.049	1.074	1.098	1.146
15	.872	.898	.932	.967	1.001	1.020	1.040	1.059	1.098
18	.865	.887	.915	.944	.973	1.001	1.017	1.033	1.066

4.7.1.5 The wheel service factor S_m is equal to 1.25 times the machinery service factor C_d, and is shown in Table 4.7.1-3 for the different service classifications. This factor recognizes that the interaction between rail and wheel is more demanding in terms of durability that well aligned and lubricated interaction of machined parts.

4.7.1.6 The wheel load service coefficient $K_{wl} = K_{wbw} \times C_s \times S_m$ with the following limitations:

K_{wl} may not be smaller than K_{wl} min. shown in Table 4.7.1-3

4.7.1.7 The equivalent durability wheel load P_e shall be determined as follows:

P_e = Maximum Wheel load x K_{wl}

The equivalent durability wheel load P_e shall not exceed the wheel load P listed in Table 4.7.1-4.

TABLE 4.7.1-3
WHEEL SERVICE FACTOR S_m AND MINIMUM
LOAD SERVICE FACTOR K_{wl} MINIMUM

CLASS OF CRANE SERVICE	A	B	C	D
K_{wl} MIN.	.75	.75	.8	.85
S_m	.8	.9	1.0	1.12

TABLE 4.7.1-4
MAXIMUM PERMISSIBLE BRIDGE WHEEL LOADING (POUNDS)

Wheel Hardness	Wheel dia. (D) inches	ASCE 20#	ASCE 25#	ASCE 30#	ASCE 40#	ARA-A 90#	ASCE 60 & 70# ARA-B 100#	ASCE 80 & 85# ARA-A 100# BETH 104# USS 105#	ASCE 100#	BETH & USS 135#
200 BHN	5	4200	5000	5300						
	6	5050	6000	6400	7500					
	8	6750	8000	8500	10000					
	9	7600	9000	9550	11250	14900	15750			
	10	8450	10000	10650	12500	16550	17500			
	12		12000	12750	15000	19850	21000	22500	25500	
	15			15950	18750	24850	26250	28150	31850	
	18			19150	22500	29800	31500	33750	38250	40500
260 BHN	5	5500	6500	6900						
	6	6600	7800	8300	9750					
	8	8800	10400	11050	13000					
	9	9850	11700	12450	14600	19400	20450			
	10	10950	13000	13800	16250	21550	22750			
	12		15600	16600	19500	25850	27300	29250	33150	
	15			20750	24400	32300	34100	36550	41450	
	18			24850	29250	38750	40950	43850	49700	52650
320 BHN	5	5850	6950	7400						
	6	7050	8350	8900	10450					
	8	9400	11150	11850	13900					
	9	10550	12550	13300	15650	20750	21950			
	10	11750	13900	14800	17400	23050	24350			
	12		16700	17750	20900	27650	29250	31300	35500	
	15			22200	26100	34600	36550	39150	44400	
	18			26650	31300	41500	43850	47000	53250	56400
58Rc (615 BHN)	5	7300	8650	9200						
	6	8750	10350	11000	12950					
	8	11650	13800	14700	17250					
	9	13100	15550	16500	19450	25750	27200			
	10	14600	17250	18350	21600	28600	30200			
	12		20700	22050	25900	34300	36250	38850	44050	
	15			27550	32400	42900	45350	48550	55050	
	18			33050	38850	51500	54400	58300	66050	69950
Effective Width of Rail Head (W) Inches (Top of head minus corner radii)		.844	1.000	1.063	1.250	1.656	1.750	1.875	2.125	2.250

Notes:
1. Allowable wheel loads for hardened wheels require depth of hardness sufficient to withstand subsurface shear stresses.
2. The 58 Rc loads are based on wheels running on heat-treated rail (320 BHN minimum). If the wheels are running on untreated rail, the above loads may cause decreased rail life.
3. The Rc/BHN conversion is based on ASTM E140, tungsten carbide ball.
4. Some rail sizes may be out of production.

4.7.1.8 Proper Clearance for Bridge Wheels

A total of approximately 3/4 inch to one inch wider than rail head. Tapered tread wheels may have a clearance over the rail head of 150 percent of the clearance provided for straight tread wheels as recommended by the crane manufacturer.

4.7.1.9 When rotating axles are used, wheels should be mounted on the axle with press fit alone, or press fit and keyed.

4.7.2 Under Running Bridge Wheels

4.7.2.1 Wheels shall be constructed of suitable material. Wheels shall be heat treated only if specified. All under running bridge truck wheels shall be designed to suit the surface on which they run. Drive wheels shall be the same diameter within a tolerance of .010 inch.

4.7.2.2 When flangeless wheels are used they and the side roller arrangement shall be the crane manufacturer's standard.

4.7.2.3 Wheels shall be designed to carry the maximum wheel load under normal conditions. The recommended wheel load shown on Table 4.7.2.3-1 is that load produced with the trolley handling the rated load in a position to exert the maximum load and may be used as a guide for wheel sizes. It should be noted that impact is not considered in these figures and for unusual conditions consideration should be given to other factors which are not included in the simple formula on which Table 4.7.2.3-1 is based. It is also important to note that a reduction in the allowable wheel load may be necessary to satisfy the runway lower flange stress requirements.

TABLE 4.7.2.3-1
GUIDE FOR MAXIMUM WHEEL LOADS FOR UNDER RUNNING CRANES

For Contour Tread*
Maximum Load (P) = 1000 WD (Pounds)

For Convex Tread
Maximum Load (P) = 600 WD (Pounds)

where: W = Width of wheel tread exclusive of flange (inches)
D = Diameter of wheel (inches)

Wheel Dia. (D) Inches	Contour Tread*				Convex Tread			
	W = 1/2"	W = 1"	W = 1 1/2"	W = 2"	W = 1/2"	W = 1"	W = 1 1/2"	W = 2"
4	2000	4000	6000	8000	1200	2400	3600	4800
5	2500	5000	7500	10000	1500	3000	4500	6000
6	3000	6000	9000	12000	1800	3600	5400	7200
7	3500	7000	10500	14000	2100	4200	6300	8400
8	4000	8000	12000	16000	2400	4800	7200	9600
9	4500	9000	13500	18000	2700	5400	8100	10800
10	5000	10000	15000	20000	3000	6000	9000	12000

*Where wheel tread matches the rolling surface of the lower flange of the track beam.

Note #1: Charted values are based on wheels with Brinell hardness of 200. Larger wheel loads are obtainable with suitable material and with greater Brinell hardness.

4.8 BUMPERS AND STOPS

4.8.1 When provided, bridge bumpers shall be rigidly mounted in such a manner that the attaching bolts are not in shear and they shall be designed and installed to minimize parts falling from the crane in the event of breakage. Bumpers and their mountings shall be of sufficient length that no other parts of either crane shall come in contact when the two cranes come together.

4.8.2 Bumpers shall have the energy absorbing (or dissipating) capacity to stop the crane when traveling with power off in either direction at a speed of at least 40% of the rated load speed. The bumpers shall also be capable of stopping the crane (not including load block and lifted load) at a rate of deceleration not to exceed an average of three (3 feet per second per second) when traveling with power off in either direction at 20% of rated load speed.

4.8.3 The size and location of the bridge bumpers shall be specified by the crane manufacturer.

4.8.4 Runway stops engaging top running wheels are not recommended.

4.8.5 Runway stops are normally designed and provided by owner or specifier and are located at the limits of the bridge travel.

4.8.6 Runway stops shall be attached to resist the force applied when contacted.

74-5 ELECTRICAL EQUIPMENT

5.1 GENERAL

5.1.1 The electrical equipment section of this Specification is intended to cover top running and under running bridge type single girder electric overhead traveling cranes for operation with alternating current or direct current power supplies.

5.1.2 The proposal of the crane manufacturer shall include the rating and description of all motors, brakes, control and protective and safety features.

5.1.3 The crane manufacturer shall furnish and mount all electrical equipment, conduit and wiring, unless otherwise specified. If it is necessary to partially disassemble the crane for shipment, all conduit and wiring affected shall be cut to length and identified to facilitate reassembly. Bridge conductors, runway collectors and other accessory equipment may be removed for shipment.

5.1.4 Wiring and equipment shall comply with Article 610 of the National Electrical Code.

5.1.5 Electrical equipment shall comply with ASME B30.11 Monorail and Underhung Cranes, ASME B30.16 Safety Standard for Overhead Hoists, and ASME B30.17 Overhead and Gantry Cranes (top running bridge, single girder, underhung hoist).

5.2 MOTORS - AC AND DC

5.2.1 Motors shall be designed specifically for crane and hoist duty and shall conform to NEMA Standard MG1 or AISE Standard No. 1 or 1A, where applicable. Designs not in accordance with these standards may be specified.

5.2.1.1 AC induction motors may be wound rotor (slip ring) or squirrel cage (single speed or multispeed) types.

5.2.1.2 DC motors may be of series, shunt, compound wound or permanent magnet type.

5.2.1.3 AC Motors used with Inverters:

5.2.1.3.1 Motors shall be AC Induction (low slip) type.

5.2.1.3.2 Motor construction shall be TENV, TEFC, motor with independent blower or open drip proof type.

5.2.1.3.3 Motor insulation should be Class F rated and should be thermally protected with sensor embedded in the motor winding.

5.2.1.3.4 Motor selection shall be based on proper horsepower calculation for the drive of the required service class. The motor's duty rating should be based on the service class and on the speed range required for the application.

5.2.2 Motor Insulations

Unless otherwise specified by the crane manufacturer, the insulation rating shall be in accordance with Table 5.2.2-1.

TABLE 5.2.2-1

NEMA Permissible Motor Winding Temperature Rise, Above 40 Degrees C Ambient, Measured by Resistance*+

A.C. Motors

Insulation Class	Open Dripproof & TEFC	TENV
B	80 Deg. C	85 Deg. C
F	105 Deg. C	110 Deg. C
H	125 Deg. C	135 Deg. C

D.C. Motors

Open Dripproof	TEFC & TENV
100 Deg. C	110 Deg. C
130 Deg. C	140 Deg. C
155 Deg. C	165 Deg. C

*If ambient temperatures exceed 40 Deg. C, the permissible winding temperature rise must be decreased by the same amount, or may be decreased per the applicable NEMA Standards.

+The crane manufacturer will assume 40 Deg. C. ambient temperature unless otherwise specified by the purchaser.

5.2.3 Motors shall be provided with anti-friction bearings.

5.2.4 Voltage

Motor rated voltage and corresponding nominal system voltage shall be in accordance with Table 5.2.4-1 (References: AC-ANSI C84.1-1977, Appendix and Table C3; also NEMA MG 1-10.62).

TABLE 5.2.4-1
NOMINAL SYSTEM AND MOTOR RATED VOLTAGE

<table>
<tr><th rowspan="2">SOURCE</th><th rowspan="2">DESCRIPTION</th><th colspan="2">Nominal System Voltage</th><th colspan="2">Motor Rated Voltage</th></tr>
<tr><th>AC</th><th>DC</th><th>Three Phase</th><th>Single Phase</th></tr>
<tr><td rowspan="13">AC</td><td rowspan="5">60 Hz (1) (2)</td><td>120</td><td rowspan="6"></td><td>—</td><td>115</td></tr>
<tr><td>208</td><td>200</td><td>—</td></tr>
<tr><td>240</td><td>230</td><td>230</td></tr>
<tr><td>480</td><td>460</td><td>—</td></tr>
<tr><td>600</td><td>575</td><td>—</td></tr>
<tr><td>50 Hz</td><td>400</td><td>380</td><td>—</td></tr>
<tr><td rowspan="7">Rectified</td><td rowspan="2"></td><td rowspan="2"></td><td colspan="2">Adjustable Voltage
Shunt or Compound</td></tr>
<tr><td>Armature</td><td>Shunt Field</td></tr>
<tr><td>400-3-60</td><td>460 Max. (9)</td><td>230 (4)</td><td>230 (5)</td></tr>
<tr><td>240-3-60</td><td>(6) (9)</td><td>240</td><td>150 or 240</td></tr>
<tr><td>460-3-60</td><td>(7) (9)</td><td>500</td><td>240 or 300</td></tr>
<tr><td rowspan="2">208
thru
600</td><td rowspan="2">(9)
500 Max.</td><td colspan="2">Constant Potential
Series, Shunt, Compound</td></tr>
<tr><td colspan="2">230 or 240 (3) (8)</td></tr>
<tr><td>DC</td><td>Generator or Battery</td><td>—</td><td>250</td><td colspan="2">230 or 240 (3) (8)</td></tr>
</table>

(1) Applicable to all nominal system voltages containing this voltage.
(2) For nominal system voltages other than shown above, the motor rated voltage should be either the same as the nominal system voltage or related to the nominal system voltage by the approximate ratio of 115 to 120. Certain kinds of equipment have a maximum voltage limit of 600 volts; the manufacturer and/or power supplier should be consulted to assure proper application.
(3) Performance will not necessarily equal rated performance when appreciable ripple is present.
(4) AISE Std. No. 1, Rev. 9-68 Electrical 2B (mill motors).
(5) AISE Std. No. 1, Rev. 9-68 Electrical 3 (mill motors).
(6) NEMA MG 1-10.62.2 & Table 10-9 (industrial motors).
(7) NEMA MG 1-10.62.2 & Table 10-10 (industrial motors).
(8) Motor rated voltage may be 250 volts for large frame motors 300 hp and larger.
(9) Maximum motor input voltage.

5.2.4.1 Variations - AC

5.2.4.1.1 Variation from Rated Voltage

All AC induction motors with rated frequency and balanced voltage applied shall be capable of accelerating and running with rated hook load at plus or minus 10 percent of rated motor voltage, but not necessarily at rated voltage performance values. (Reference NEMA MG 1-12.45).

5.2.4.1.2 Voltage Unbalance

AC polyphase motors shall be capable of accelerating and running with rated hook load when the voltage unbalance at the motor terminals does not exceed 1 percent. Performance will not necessarily be the same as when the motor is operating with a balanced voltage at the motor terminals. (Reference NEMA MG 1-12.46)

5.2.4.2 **Variations - DC**

DC motors shall be capable of accelerating and running with rated hook load with applied armature and field voltages up to and including 110 percent of the rated values of the selected adjustable voltage power supply. With rectified power supplies successful operation shall result when AC line voltage variation is plus or minus 10 percent of rated voltage. Performance will not necessarily be in accordance with the standards for operation at rated voltage. (Reference NEMA MG 1-12.68).

5.2.5 Operation with voltage variations beyond those shown in Sections 5.2.4.1 and 5.2.4.2. Operation at reduced voltage may result in unsatisfactory drive performance with rated hook load such as reduced speed, slower acceleration, increased motor current, noise, and heating. Protective devices may operate stopping the drive in order to protect the equipment. Operation at elevated voltages may result in unsatisfactory operation, such as, excessive torques. Prompt corrective action is recommended; the urgency for such action depends upon many factors such as the location and nature of the load and circuits involved and the magnitude and duration of the deviation of the voltage. (References ANSI C84.1.2.4.3 range, B also IEEE Standard 141).

5.2.6 Deviations from rated line frequency and/or combinations of deviations of line frequency and voltage may result in unsatisfactory drive operation. These conditions should be reviewed based on the type of drive used.

5.2.7 **Motor Time Ratings**

Single speed motors shall be rated on no less than a 30 minute basis with temperature rise in accordance with the latest NEMA standards for the class of insulation and enclosure used, unless otherwise specified.

5.2.7.1 Multispeed motors may be rated less than 30 minutes on the low speed winding so long as the crane builder data sheets so indicate.

5.2.7.2 Under unusual conditions, such as long lifts at reduced speeds, abnormal inching or jogging requirements, short repeated travel drive movements, altitudes over 3,300 feet above sea level, abnormal ambient temperatures, etc., the motor time rating must be increased accordingly.

5.2.8 **Bridge Motor Size Selection**

5.2.8.1 The bridge motor rating using either AC or DC power, is basically the mechanical horsepower with considerations for the effect of control, and ambient temperature.

5.2.8.1.1 Indoor bridge motor required horsepower

Required Motor Horsepower:

The bridge motor shall be selected so that the horsepower rating is not less than that given by the following formula:

$$HP = K_a \times W \times V \times K_s$$

where: K_a = acceleration factor for type of motor used

K_s = service factor which accounts for the type of drive and duty cycle.

K_s = 1.0 for AC magnetic and DC adjustable voltage controls. For other types of control consult control manfacturer.

W = total weight to be moved including all dead and live loads (tons)

V = rated drive speed (FPM)

For the general case of bridge drives:

$$K_a = \frac{f + \frac{2000a \times C_r}{g \times E}}{33{,}000 \times K_t} \times \frac{N_r}{N_f}$$

where: f = rolling friction of drive (including transmission losses) in pounds per ton (Ref. Table 5.2.8.1.1-D).

a = average or equivalent uniform acceleration rate in feet per second per second up to rated motor rpm. For guidance, see Table 5.2.8.1.1-A and Table 5.2.8.1.1-B.

C_r = rotational inertia factor.

$$= \frac{WK^2 \text{ of crane \& load} + WK^2 \text{ of rotating mass}}{WK^2 \text{ of crane \& load}}$$

or 1.05 + (a/7.5) if WK^2 is unknown

g = 32.2 feet per second per second

E = mechanical efficiency of drive machinery expressed as a per unit decimal. For guidance see Table 5.2.8.1-1.

N_r = rated speed of motor in rpm at full load.

N_f = free running rpm of motor when driving at speed V (see also Section 5.2.9.1).

K_t = equivalent steady state torque relative to rated motor torque which results in accelerating up to rated motor rpm (N_r) in the same time as the actual variable torque speed characteristic of the motor and control characteristic used. See Table 5.2.8.1.1-C for typical values of K_t.

TABLE 5.2.8.1-1
Typical Efficiency Values

Bearings	E*
Anti-friction	.97
Sleeve	.93

*Note: The values of gear efficiency shown apply primarily to spur, herringbone and helical gearing, and are not intended for special cases such as worm gearing, friction drives, chain drives etc.

TABLE 5.2.8.1.1-A
Guide for Bridge Motion
Typical Acceleration Rates Range[1]

Free Running Full Load Speed		a = Acceleration Rate in Feet per Sec. per Sec. for AC or DC[2] Motors
Ft. per Min.	Ft. per Sec.	
60	1.0	.25 Min.
120	2.0	.25 - .80
180	3.0	.30 - 1.0
240	4.0	.40 - 1.0
300	5.0	.50 - 1.1

[1]: The actual acceleration rates shall be selected to account for proper performance including such items as acceleration time, free running time, motor and resistor heating, duty cycle, load spotting capability, and hook swing. (The acceleration rates shall not exceed the values shown in table 5.2.8.1.1-A.) To avoid wheel skidding the acceleration rate should not exceed the values shown in Table 5.2.8.1.1-B.

[2]: For DC series motors the acceleration rate 'a' is the value occuring while on series resistors. This would be in the range of 50 to 80 percent of the free running speed (N_f).

TABLE 5.2.8.1.1-B
Guide For
Maximum Acceleration Rate to Prevent Wheel Skidding

Percent of Driven Wheels	100	50	33.33	25	16.67
Maximum Acceleration Rate Feet per Sec. per Sec. - Dry Rails - Based on .2 Coefficient of Friction	4.8	2.4	1.6	1.2	.8
Acceleration Rate - Wet Rails - Based on .12 Coefficient of Friction	2.9	1.5	1.0	.7	.5

The values in the above table are based upon the peak acceleration torque being equal to 1.33 times the average acceleration torque.

TABLE 5.2.8.1.1-C
Recommended Values of K_t
(Accelerating Torque Factor)

Type of Motor	Type of Control	K_t[1]
AC Wound Rotor	Contactor-Resistor	1.3 - 1.5[2]
AC Wound Rotor	Static Stepless	1.3 - 1.5[2]
AC Sq. Cage	Ballast Resistor	1.3
AC Inverter	Inverter	1.5
DC Shunt Wound	Adjustable Voltage	1.5
DC Series Wound	Contactor-Resistor	2.0

[1]K_t is a function of control and/or resistor design.
[2]Low end of range is recommended when permanent slip resistance is used.

TABLE 5.2.8.1.1-D
Suggested Values for f (Friction Factor) for Bridges
with Metallic Wheels & Anti-Friction Bearings

Wheel Dia. Inches		18	15	12	10	8	6	5	4
Friction Lb/Ton (f)	Top Running	15	15	15	15	16	16	18	20
	Under Running	—	18	18	18	20	20	22	

Note 1 - For cranes equipped with sleeve bearings of normal proportions, a friction factor of 24 pounds per ton may be used.

Note 2 - The above friction factors may require modifications for other variables such as low efficiency worm gearing, non-metallic wheels, special bearings, and unusual rail conditions.

5.2.8.1.2 Latitude is permitted in selecting the nearest rated motor horsepower over or under, the required horsepower to utilize commercially available motors. In either case, consideration must be given to proper performance of the drive.

5.2.8.1.3 Outdoor Cranes: Bridge drive motor horsepower for outdoor cranes.

Errata Sheet - CMAA Specification #74, Revised 2004

Under 74-5 Electrical Equipment, page 48, paragraph 5.2.8.1.3.3, the following corrected formula should be used: Required motor horsepower = $(HP_F + HP_W)\ K_S$

5.2.8.1.3.1 Compute the free running bridge motor horsepower (HP_F) at rated load and rated speed, neglecting any wind load, using the following formula:

$$HP_f = \frac{W \times V \times f}{33000}$$

where: W = full load weight to be accelerated (tons)

V = full load speed (fpm)

f = friction factor (pounds per ton) per Table 5.2.8.1-1D

5.2.8.1.3.2 Compute the free running bridge motor horsepower due to wind force only (HP_w) using the following formula:

$$HP_w = \frac{P \times \text{wind area} \times V}{33000 \times E}$$

where: P = wind pressure (pounds per square foot) computed from the formula $P = .00256(V_w)^2$

V_w= the wind velocity (mph).

When V_w is unspecified, P = 5 pounds per square foot should be used.

Wind area = effective crane surface area exposed to wind in square feet as computed in Section 3.3.2.1.2.1.

V = full load speed (fpm).

E = bridge drive mechanical efficiency.

5.2.8.1.3.3 The bridge drive motor shall be selected so that its horsepower rating is not less than given by the following formula:

Required motor horsepower = $(HP_F + HP_w)\ K_s$

using HP_F and HP_w as computed above.

where: K_S = service class factor per section 5.2.8.1.1.

5.2.8.1.3.4 The following items must be considered in the overall bridge drive design to assure proper operation under all specified load and wind conditions:

a. Proper speed control, acceleration and braking without wind.

b. Ability of control to reach full speed mode of operation against wind.

c. Bridge speed, on any control point, when traveling with the wind not to exceed the amount resulting in the maximum safe speed of the bridge drive machinery.

d. Avoidance of wheel skidding which could likely occur under no load, low percent driven wheels and wind conditions.

e. Sufficient braking means to maintain the bridge braking requirements.

5.2.9 Bridge Drive Gear Ratios

$$\text{Bridge drive gear ratio} = \frac{N_f \times D_w \times \pi}{V \times 12}$$

where: N_f = free running rpm of the motor, after the drive has accelerated, with rated load to the steady state speed V.

The value of N_f is established from the motor-control speed-torque curves at free running horsepower (HP_{FR}).

$$HP_{FR} = \frac{W \times f \times V}{33000}$$

Where:
W = total load (tons)
f = rolling friction (pounds per ton) per Table 5.2.8.1.1-D
V = specified full load travel drive speed (fpm)
D_w = wheel tread diameter (inches)

5.2.9.1 Variations from the calculated gear ratio is permissible to facilitate the use of standard available ratios, provided that motor heating and operational performance is not adversely affected. The actual full load drive speed may vary a maximum of ± 10 percent of the specified full load speed.

5.3 BRAKES

5.3.1 Types of electrical brakes for the bridge when provided shall be specified by the crane manufacturer.

5.3.2 Refer to section 4.4 of this Specification for bridge brake selection and rating.

5.3.3 Holding brakes if provided shall be applied automatically when power to the brake is removed.

5.3.4 On direct current shunt brakes, it may be desirable to include a forcing circuit to provide rapid setting and release.

5.3.5 Brake coil time rating shall be selected for the duration and frequency of operation required by the service.

5.3.6 Brake for the trolley is recommended with use of an inverter when proper braking and three phase monitoring is not provided in the VFD.

5.4 CONTROLLERS, ALTERNATING AND DIRECT CURRENT

5.4.1 **Scope** - This section covers requirements for selecting and controlling the direction, speed, acceleration and electrical braking of the bridge and travel motors. Other control requirements such as protection and master switches are covered in other sections. **This section also covers the requirements for hoist and trolley travel controls if not supplied as an integral part of the monorail hoist.**

5.4.2 On cranes with a combination of cab with master switches, and pendant floor control, the applicable Specifications for cab controlled cranes shall apply. On floor operated cranes where the pendant master is also used in a "skeleton" cab, the applicable Specifications for floor controlled cranes shall apply.

5.4.3 On remote controlled cranes, such as by radio or carrier signal the applicable floor control Specifications shall apply, unless otherwise specified.

5.4.4 Control systems may be manual, magnetic, static, variable frequency or variable voltage DC or in combination as specified.

5.4.4.1 Hoists shall be furnished with a control braking means, either mechanical or power. Typical mechanical means include mechanical load brakes or self-locking worm drives. Typical power means include dynamic lowering, eddy-current braking, counter-torque, regenerative braking.

5.4.4.2 Bridge and Trolley Travel

With the exception of floor operated pendant control class A, B & C cranes, all bridges and trolleys shall be furnished with reversing control systems incorporating plugging protection. Typical plugging protection includes a magnetic plugging contactor, ballast resistors, slip couplings, motor characteristics, or static controlled torque.

5.4.5 Magnetic Control

5.4.5.1 Each magnetic control shall have contactors of a size and quantity for starting, accelerating, reversing, and stopping, and for the specified CMAA crane service class. All reversing contactors shall be mechanically and electrically interlocked.

5.4.5.2 The minimum NEMA size of magnetic contactors shall be in accordance with Tables 5.4.5.2-1 AC Wound Rotor, 5.4.5.2-2 AC Squirrel Cage, 5.4.5.2-3 DC, and Tables 5.6.6-1 and 5.6.6-2 Mainline Service. Definite purpose contactors specifically rated for crane and hoist duty service may be used for CMAA crane service classes A, B, and C provided the application does not exceed the contactor manufacturer's published ratings. IEC Contactors may be used for Crane and Hoist duty service provided the application does not exceed the contactor manufacturer's published ratings.

TABLE 5.4.5.2-1

AC CONTACTOR RATINGS FOR WOUND ROTOR MOTORS

Size of Contactor	8-hour Open Rating Amperes	Maximum Intermittent Rating[1]		
		Amperes*	Horsepower at	
			230 Volts	460 and 575 Volts
0	20	20	3	5
1	30	30	7 1/2	10
2	50	67	20	40
3	100	133	40	80

[1]Wound rotor primary contactors shall be selected to be not less than the current and horsepower ratings. Wound rotor secondary contactors shall be selected to be not less than the motor full load secondary current, using contactor intermittent rating. The ampere intermittent rating of a three pole secondary contactor with poles in delta shall be 1 1/2 times its wound rotor intermittent rating.

TABLE 5.4.5.2-2

AC CONTACTOR RATINGS FOR SQUIRREL CAGE MOTORS

MAXIMUM INTERMITTENT HORSEPOWER RATING

Size of Contactor	230 Volts	460 and 575 Volts
0	3	5
1	7 1/2	10
2	15	25*
3	30*	50*

*Squirrel cage motors over 20 horsepower are not normally used for crane motions.

TABLE 5.4.5.2-3

DC CONTACTOR RATINGS FOR 230 VOLT CONTROLS[1]

Size of Contactor	8-hour Open Rating Amperes	Maximum Intermittent Rating	
		Amperes	Horsepower
1	25	30	7 1/2
2	50	67	15
3	100	133	35

[1]For constant potential DC drives other than 230 to 250 volts, refer to NEMA ICS 8 part 3 Table 3-4-1.

For adjustable voltage DC drives at voltage other than 230 volts, the contactor horsepower ratings will be directly proportional to the voltage up to a maximum of 600 volts.

5.4.5.3 The minimum number of resistor stepping contactors, time delay devices and speed points for AC wound rotor motors and DC motors shall be as shown in Table 5.4.5.3-1.

TABLE 5.4.5.3-1
MINIMUM NUMBER OF RESISTOR STEPPING CONTACTORS, TIME DELAY DEVICES AND SPEED POINTS FOR MAGNETIC CONTROL

HORSEPOWER	MIN. NO. OF RESISTOR STEPPING CONTACTORS (See Note 1)			MIN. NO. OF TIME DELAY DEVICES (See Note 2)			MIN. NO. OF SPEED POINTS (See Note 3)		
	CMAA CLASS			CMAA CLASS			CMAA CLASS		
	A, B	C	D	A, B	C	D	A, B	C	D
	AC WOUND ROTOR SECONDARY RESISTORS CAB CONTROL CRANES								
Less than 8	2*	3	3	1	2	2	3	4	4
8 thru 15	3	3	3	1	2	2	4	4	4
16 thru 30	3*	4	4	1	3	3	4	5	5
	AC WOUND ROTOR SECONDARY RESISTORS FLOOR CONTROL CRANES								
Less than 30	2	2	3	1	1	2	3	3	4
Greater than 30	Same as for cab control cranes								
	DC MOTOR SERIES RESISTORS @230 VOLTS CAB CONTROL CRANES								
Less than 8	3	3	3	1	2	2	4	4	4
8 thru 15	3	4	4	1	3**	3**	4	5	5
16 thru 35	3	4	4	1	3**	3**	4	5	5
	DC MOTOR SERIES RESISTORS @ 230 VOLTS FLOOR CONTROL CRANES								
0 thru 15	2	2	3	1	1	2	3	3	4
16 thru 30	3	3	4	2	2	3	4	4	5
Greater than 30	Same as for cab control cranes								

*A 10 percent slip resistance or one (1) additional contactor shall be provided on bridge and trolley drives.

**Numbers shown apply to bridge and trolley drives. For hoists, a minimum of two (2) time delay devices are required in the hoisting direction.

Note 1: One (1) contactor of the number shown may be used for plugging on bridge or trolley controls or low torque on hoist controls.

If more than one (1) plugging step is used, additional contactors may be required.

Note 2: Plugging detection means shall be added to prevent closure of the plugging contactors until the bridge or trolley drive has reached approximately zero speed.

Note 3: A speed point may be manual hand controlled, or automatic, as required.

The minimum number of operator station hand controlled speed points shall be three (3) in each direction except as follows:

(a) Class C and D cab operated hoist controllers with four (4) or more resistor stepping contactors shall have a minimum of five (5) hand controlled speed points in each direction.

(b) Class A and B, controllers for AC wound rotor motors less than 8 horsepower shall have a minimum of two (2) hand controlled speed points in each direction.

(c) Controllers for floor operated bridge and trolley motions shall have a minimum of one (1) hand controlled speed points in each direction.

(d) When specified, a drift point (no motor power, brake released) shall be included as a hand controlled speed point in addition to the above minimum requirements for bridge and trolley motions.

5.4.5.4 On multi-motor drives, the contactor requirements of this section apply to each motor individually, except if one set of line reversing contactors is used for all motors in parallel, then the line contactors shall be sized for the sum of the individual horsepowers. The resistor stepping contactors may be common multipole devices, if desired. An individual set of acceleration resistors for each motor shall be provided unless otherwise specified. Timing shall be done with one (1) set of time delay devices.

5.4.6 Static Control

5.4.6.1 Static power components such as rectifiers, reactors, resistors, etc., as required shall be sized with due consideration of the motor ratings, drive requirements, service class, duty cycle, and application in the control.

5.4.6.2 Magnetic contactors, if used shall be rated in accordance with Section 5.4.5.2.

5.4.6.3 Static control systems may be regulated or non-regulated, providing stepped or stepless control using AC or DC motors, as specified.

5.4.6.4 Travel drives systems may be speed and/or torque regulated, as specified. If a speed regulated system is selected the method of deceleration to a slower speed may be by drive friction or drive torque reversal, as specified. Hoist drives are assumed to be inherently speed regulated and due consideration shall be given to the available speed range, the degree of speed regulation, and optional load float.

5.4.6.5 Primary reversing of AC motor drives shall be accomplished with magnetic contactors or static components as specified. When static components are used, a line contactor shall be furnished for the drive.

5.4.6.6 Current and torque limiting provisions shall be included not to exceed the motor design limitations, and with consideration for desired acceleration.

5.4.6.7 Control torque plugging provisions shall be included for bridge or trolley drives.

5.4.6.8 Permanent slip resistance may be included providing due consideration is given to the actual motor speeds under rated conditions.

5.4.6.9 The crane Specifications shall state whether the hoist motor horsepower used with static control is on the basis of average hoisting and lowering speed with rated load or on the basis of actual hoisting speed to raise rated load.

5.4.7 Enclosures

5.4.7.1 Control panels should be enclosed and shall be suitable for the environment and type of control. The type of enclosure shall be determined by agreement between the purchaser and the crane manufacturer. A typical non-ventilated enclosure may be in accordance with one of the following NEMA Standards publication ICS6 classifications:

ENCLOSURES FOR NON-HAZARDOUS LOCATIONS

Type 1 – General purpose - Indoor.
Type 1-A – General purpose - Indoor - Gasketed.
(Note: Type 1-A enclosure is not currently recognized by NEMA)
Type 2 – Drip-proof - Indoor.
Type 3 – Dust-tight, rain-tight and sleet-resistant, ice-resistant - Outdoor.
Type 3R – Rain-proof and sleet-resistant, ice-resistant - Outdoor.
Type 3S – Dust-tight, rain-tight and sleet (ice)-proof - Outdoor.
Type 4 – Water-tight and dust-tight - Indoor and Outdoor.

Type 4X – Water-tight, dust-tight and corrosion-resistant - Indoor and Outdoor.
Type 12 – Industrial Use - Dust-tight and drip-tight - Indoor.
Type 13 – Oil-tight and dust-tight - Indoor.

ENCLOSURES FOR HAZARDOUS LOCATIONS

Type 7 – Class I, Division I and II, Group A, B, C, or D - Indoor Hazardous Locations - Air-break Equipment.

Type 9 – Class II, Division I and II, Group E, F, or G - Indoor Hazardous Locations - Air-break Equipment.

5.4.7.2 Enclosures containing devices that produce excessive heat or ozone or devices that require cooling for proper operation, may require ventilation means. These enclosures shall be equipped with the necessary ventilation such as louvers or forced cooling. Air filters or similar devices may be necessary depending on the environment. Since the original definition of the enclosure per its specified type may be somewhat altered by the nature of the ventilation means, the final design shall meet the functional intent.

5.4.7.3 Unless otherwise specified, enclosures for electrical equipment other than controls shall be suitable for the environment, and in accordance with the following practices:

(a) Auxiliary devices such as safety switches, junction boxes, transformers, pendant masters, lighting panels, main line disconnects, accessory drive controls, brake rectifier panels, limit switches, etc., may be supplied in enclosures other than specified for the control panel.

(b) Resistor covers for indoor cranes, required to prevent accidental contact under normal operating conditions, shall include necessary screening and ventilation. Resistor covers for outdoor cranes shall be adequately ventilated.

(c) Brake covers:
1. Brakes, for indoor cranes, may be supplied without covers.
2. Brakes, for outdoor cranes, shall be supplied with covers.

5.5 RESISTORS

5.5.1 Resistors (except those in permanent sections) shall have a thermal capacity of not less than NEMA Class 150 series for CMAA crane service classes A, B and C and not less than NEMA Class 160 series for CMAA service class D.

5.5.2 Resistors used with power electrical braking systems on AC hoists not equipped with mechanical load brakes shall have a thermal capacity of not less than NEMA Class 160 series.

5.5.3 Resistors shall be designed to provide the proper speed and torque as required by the control system used.

5.5.4 Resistors shall be installed with adequate ventilation, and with proper supports to withstand vibration and to prevent broken parts or molten metal falling from the crane.

5.6 PROTECTION AND SAFETY FEATURES

5.6.1 A crane disconnecting means, either a current-rated circuit breaker or motor rated switch, lockable in the open position, shall be provided in the leads from the runway contact conductors or other power supply.

5.6.2 The continuous current rating of the switch or circuit breaker in Section 5.6.1 shall not be less than 50 percent of the combined short time motor full load currents, nor less than 75 percent of the sum of the short time full load currents of the motors required for any single crane motion, plus any additional loads fed by the device.

5.6.3 The disconnecting means in Section 5.6.1 shall have an opening means located where it is readily accessible to the operator's station, or a mainline contactor connected after the device in Section 5.6.1 may be furnished and shall be operable from the operator's station.

5.6.4 Power circuit fault protection devices shall be furnished in accordance with NEC Sections 110-9 Interrupting Rating. The user shall state the available fault current or the crane manufacturer shall state in the Specification the interrupting rating being furnished.

5.6.5 Branch circuit protection shall be provided per NEC Section 610-42 Branch Circuit Protection.

5.6.6 Magnetic Mainline contactors, when used, shall be as shown in Tables 5.6.6-1 and 5.6.6-2. The size shall not be less than the rating of the largest primary contactor used on any one motion.

TABLE 5.6.6-1
AC CONTACTORS RATINGS
FOR MAINLINE SERVICE

Size of Contactor	8-hour Open Rating Amperes	Maximum Intermittent Duty Rating Amperes	Maximum Total Motor Horsepower		Maximum Horsepower for any Motion	
			230 Volts	460 and 575 Volts	230 Volts	460 and 575 Volts
0	20	20	6	6	3	5
1	30	30	10	20	$7\frac{1}{2}$	10
2	50	67	30	60	20	40
3	100	133	63	125	40	80

TABLE 5.6.6-2
RATINGS AT 230 TO 250 VOLTS OF DC CONTACTORS
FOR MAINLINE SERVICE

Size of Contactor	8-hour Open Rating Amperes	Maximum Intermittent Duty Rating Amperes	Maximum Total Motor Horsepower	Maximum Horsepower for any Motion
1	25	30	10	$7\frac{1}{2}$
2	50	67	22	15
3	100	133	55	35

5.6.7 Motor running overcurrent protection shall be provided in accordance with NEC 610-43 Motor Overload Protection.

5.6.8 Control circuits shall be protected in accordance with NEC 610-53 overcurrent protection.

5.6.9 Undervoltage protection shall be provided as a function of each motor controller, or an enclosed protective panel, or a magnetic mainline contactor, or a manual-magnetic disconnect switch.

5.6.10 Cranes not equipped with spring-return controllers, spring-return master switches, or momentary contact pushbuttons, shall be provided with a device which will disconnect all motors from the line on failure of power and will not permit any motor to be restarted until the controller handle is brought to the "off" position, or a reset switch or button is operated.

5.6.11 Remote radio cranes shall be provided with a permissive radio signal in addition to a crane motion radio signal, and both signals shall be present in order to start and maintain a crane motion.

5.6.12 On automatic cranes, all motions shall be discontinued if the crane does not operate in accordance with the automatic sequence of operation.

5.6.13 Working space dimensions shall apply only to bridge mounted control panel enclosures or switching devices that are serviceable from a crane mounted walkway. The horizontal distance from the surface of the enclosure door to the nearest metallic or other obstruction shall be a minimum of 30 inches. In addition, the work space in front of the enclosure shall be at least as wide as the enclosure and shall not be less than 30 inches wide.

5.6.14 Warning Devices

5.6.14.1 Except for floor-operated cranes a gong or other effective warning signal shall be provided for each crane equipped with a power traveling mechanism.

5.6.14.2 Owner or Specifier, having full knowledge of the environment in which the crane will be operated, is responsible for the adequacy of the warning devices.

5.7 MASTER SWITCHES

5.7.1 Cab controlled cranes shall be furnished with master switches for hoist, trolley and bridge motions, as applicable, that are located within reach of the operator.

5.7.2 Cab master switches shall be provided with a notch, or spring return arrangement latch, which, in the "off" position prevents the handle from being inadvertently moved to the "on" position.

5.7.3 The movement of each master switch handle should be in the same general direction as the resultant movement of the load, except as shown in Figures 5.7.3a and 5.7.3b, unless otherwise specified.

5.7.4 The arrangement of master switches should conform to Figures 5.7.3a and 5.7.3b, unless otherwise specified.

5.7.5 The arrangement of other master switches, lever switches or pushbuttons for controller, other than hoist, trolley or bridge, (such as grabs, magnetic disconnects, turntables, etc.) are normally specified by the manufacturer.

5.7.6 If a master switch is provided for a magnet controller, the 'lift' direction shall be toward the operator and the 'drop' direction away from the operator.

5.7.7 Cranes furnished with skeleton (dummy) cabs are to be operated via the pendant pushbutton station and thereby do not require master switches unless otherwise specified by the purchaser.

5.7.8 Master switches shall be clearly labeled to indicate their functions.

5.8 FLOOR OPERATED PENDANT PUSHBUTTON STATIONS

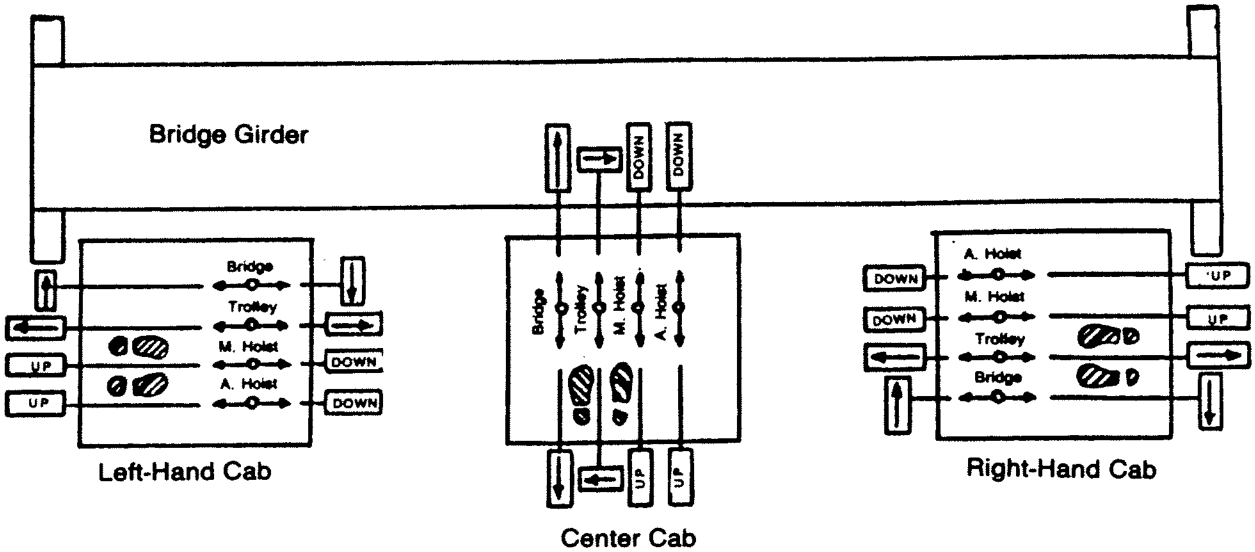
5.8.1 The arrangement of pendant pushbutton stations should conform to Figure 5.8.1 unless otherwise agreed between the manufacturer and owner.

5.8.2 Pushbuttons shall return to the "off" position when pressure is released by the crane operator.

5.8.3 Pendant pushbutton stations shall have a grounding conductor between a ground terminal in the station and the crane.

5.8.4 The maximum voltage in pendant pushbutton stations shall be 150 Volts AC or 300 Volts DC.

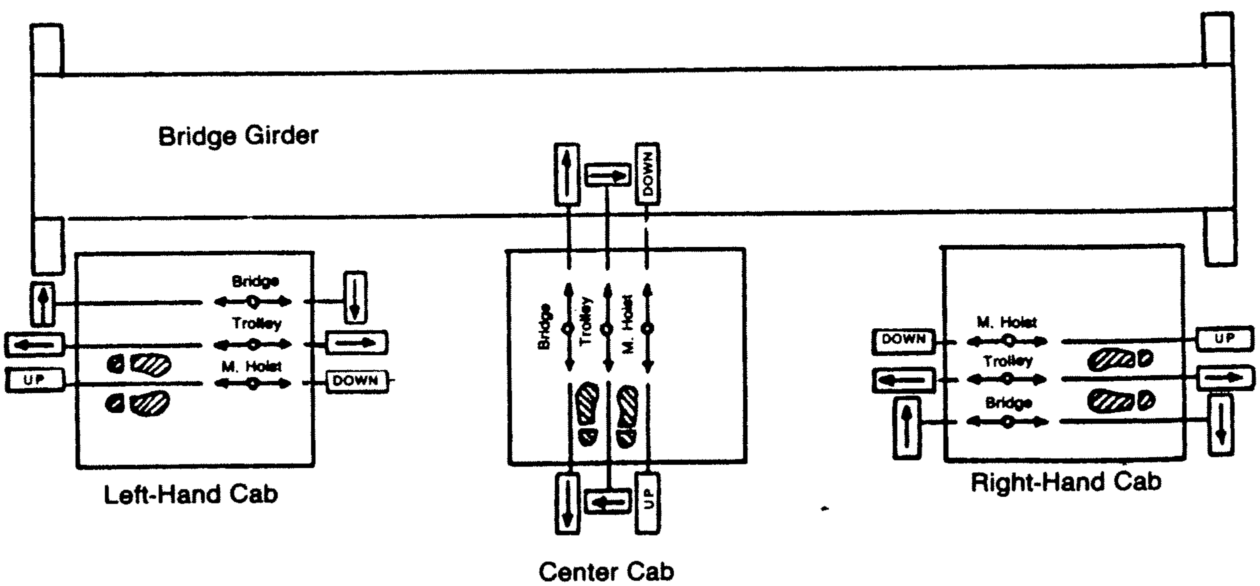
5.8.5 Pushbuttons shall be guarded or shrouded to prevent accidental actuation of crane motions.



4 Motor Crane

RECOMMENDED ARRANGEMENT OF CONTROLLERS

Fig. 5.7.3a



3 Motor Crane

RECOMMENDED ARRANGEMENT OF CONTROLLERS

Fig. 5.7.3b

5.8.6 'Stop' pushbuttons shall be colored red.

5.8.7 Pendant pushbutton station enclosures shall be as defined in Section 5.4.7.3(a).

5.8.8 Pendant pushbutton stations shall be supported in a manner that will protect the electrical conductors against strain.

5.8.9 Minimum wire size of multiconductor flexible cords for pendant pushbutton stations shall be #16 AWG unless otherwise permitted by Article 610 of the National Electrical Code.

5.9 LIMIT SWITCHES

5.9.1 The hoist motion of all cranes shall be equipped with an overtravel limit switch in the raising direction to stop hoisting motion.

5.9.2 Interruption of the raising motion shall not interfere with the lowering motion. Lowering of the block shall automatically reset the limit switch unless otherwise specified.

5.9.3 The upper limit switch shall be power circuit type, control circuit type or as specified by the purchaser. The manufacturer's proposal shall state which type is being furnished.

5.9.4 Lower limit switches shall be provided where the hook can be lowered beyond the rated hook travel under normal operating conditions and shall be of the control circuit type.

5.9.5 Trolley travel and bridge travel limit switches, when specified shall be of the control circuit type.

5.9.6 The trip point of all limit switches shall be located to allow for maximum runout distance of the motion being stopped for the braking system being used.

5.10 INSTALLATION

5.10.1 Electrical equipment shall be so located or enclosed to prevent the operator from accidental contact with live parts under normal operating conditions.

5.10.2 Electrical equipment shall be installed in accessible locations and protected against ambient environmental conditions as agreed to by the purchaser and the crane manufacturer.

5.11 BRIDGE CONDUCTOR SYSTEMS

5.11.1 The bridge 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 sized and installed in accordance with Article 610 of the National Electrical Code.

5.11.2 If local conditions require enclosed conductors, they must be specified by owner or specifier.

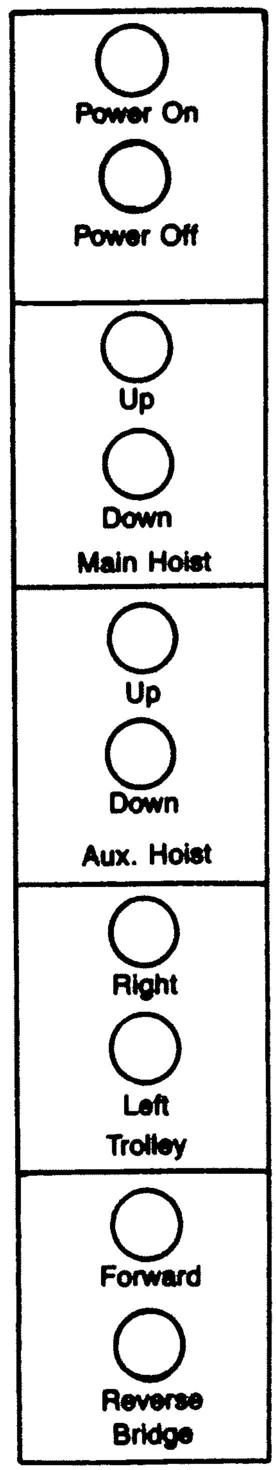
5.11.3 The crane manufacturer shall state the type conductors to be furnished.

5.11.4 The published crane intermittent ratings of manufactured conductor systems shall not be less than the ampacity required for the circuit in which they are used.

FIGURE 5.8.1

PENDANT PUSHBUTTON STATION ARRANGEMENT

In each user location, the relative arrangement of units on crane pendant pushbutton stations should be standardized. In the absence of such standardization, suggested arrangement is shown in Figure 5.8.1.



5.11.5 Current collectors, if used, shall be compatible with the type of contact conductors furnished and shall be rated for the ampacity of the circuit in which they are used. Two (2) sets of current collectors shall be furnished for all contact conductors that supply current to a lifting magnet.

5.11.6 For grounding purposes, a separate grounding conductor should be provided.

5.12 RUNWAY CONDUCTOR SYSTEMS

5.12.1 Refer to Section 1.5 of 74-1 General Specifications for information on runway conductors.

5.12.2 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.

5.12.3 For grounding purposes, a separate grounding conductor should be provided.

5.13 VOLTAGE DROP

5.13.1 The purchaser shall furnish actual voltage at the runway conductor supply taps not more than 105 percent and not less than 96 percent of the nominal system voltage, and shall define the requirements of the runway conductor system to achieve an input voltage not less than 93 percent of the nominal system voltage of the crane at the point of runway conductor collection farthest from the runway conductor supply taps.

5.13.2 The crane manufacturer shall limit the voltage drops within the crane to the motors and other electrical loads to approximately 2 percent of the nominal system voltage.

5.13.3 All voltage drops in Section 5.13.1 and 5.13.2 shall be computed by using main feeder currents, individual motor currents, fixed load currents, and demand factors of multiple cranes on the same runway as defined by Article 610 of the National Electrical Code.

5.13.4 Voltage drops shall be calculated during maximum inrush (starting) conditions to insure that motor terminal voltages are not less than 90 percent of rated motor voltage, and control and brake voltages are not less than 85 percent of device rated voltages.

5.13.5 The operating voltages at the crane motor terminals shall not exceed 110 percent or not drop below 95 percent of motor ratings, for rated running conditions, to achieve the results defined in Section 5.2.4 (voltage).

5.14 INVERTERS (VARIABLE FREQUENCY DRIVES)

5.14.1 Inverter selection shall be based on inverter manufactures recommendation given due consideration of the following: Crane class of service, application, operating environment, power supply and full load motor current. Inverter continuous current must be equal to or greater than full load motor current. Overload capacity = 1.5X full load motor current for 60 seconds.

5.14.2 Inverter drives shall be provided with dynamic braking function or fully regenerative capability. The dynamic braking and inverter duty shall meet the requirements of the drives service class.

5.14.3 Inverters shall be provided with proper branch circuit protection on the line side.

5.14.4 Distorted waveforms on the line and/or short circuit current may require the use of isolation transformers, filter or line reactors.

5.14.5 Line contactor shall be used with inverters for hoisting applications to disconnect power from drive in case of overspeed or fault.

5.14.6 All inverters shall have overspeed protection. Mechanical load brake may be considered as overspeed protection for hoisting motion.

Dynamic braking resistors may be considered as overspeed protection for horizontal drives.

5.14.7 A minimum of two collectors for each runway conductor shall be furnished with inverter use.

5.15 REMOTE CONTROL

5.15.1 Remote control may be by means of radio or infrared transmission or an off-crane control station connected to the crane through wiring. The control station may consist of pushbuttons, masterswitches, computer keyboards or combination thereof. For definition of remote control, see the applicable ANSI/ASME standards.

5.15.2 The selection and application of the remote control system should be done to assure compatibility between the remote control and the crane control system and eliminate interference.

5.15.3 When more than one control station is provided, electrical interlocks shall be included in the system to permit operation from only one station at a time. Electrical interlock is defined as effective isolation of the control circuits with the use of rotary switch contacts, relay contacts or with the use of a programmable logic controller and its input/output modules.

5.15.4 Due consideration should be given to elimination of interference between electronic signals and power circuits. This includes physical and electrical separation, shielding, etc.

5.15.5 Due consideration should be given to the following:

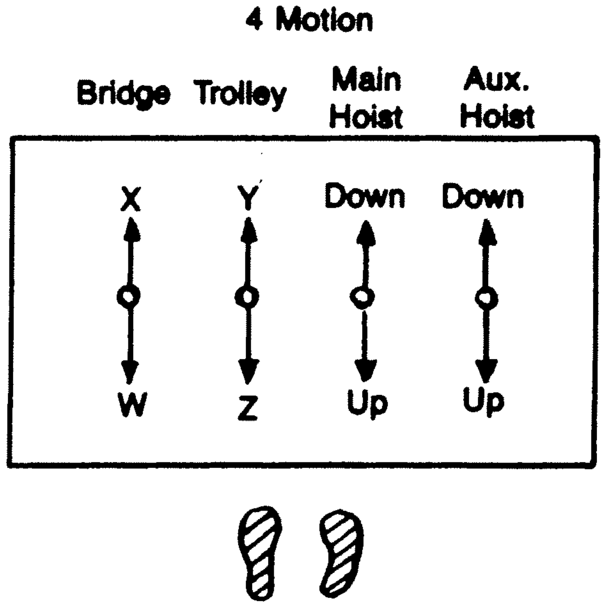
(a) Operating range of the remote control equipment.
(b) Operating speeds of the crane.
(c) Application of end travel limit switches.
(d) Wiring of magnet and vacuum circuits to the line side of the disconnecting means and use of latching controls.

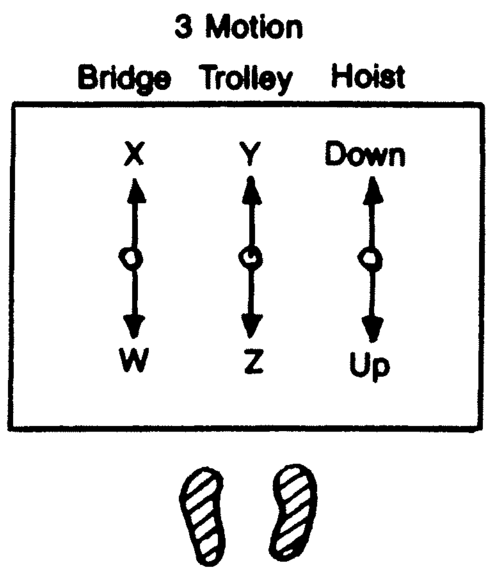
5.15.6 See Figure 5.15.6 for traditional radio transmitter lever arrangement. Transmitter arrangements other than as shown (belly box style) may be used.

5.15.7 Power disconnecting circuits and warning device shall be provided.

FIGURE 5.15.6

RADIO CONTROL TRANSMITTER LEVER ARRANGEMENT





NOTE:

Markings on the crane, visible from the floor, shall indicate the direction of bridge and trolley travel corresponding to the W, X, Y and Z designations on the transmitter.

The letters used are only intended for the purpose of illustration.

Designations should be selected as appropriate to each installation.

74-6 CRANE INQUIRY DATA SHEET
(Figure 6.1)

Customer ______________________

____

Spec. No. ______________________

Date ______________________

---

1. Number of Cranes Required ______________________

2. Capacity: Hoist(s)__________ Tons.

3. Required Hook Lift (Max. Including Pits or Wells Below Floor Elevation)
   Hoist __________ Ft. __________ In.

4. Approximate Length of Runway: __________ Ft.

5. Number of Cranes on Runway: ______________________

6. Service Information: (Description of Use)

   Hoist:
   Number of Lifts per Hour __________ Hours per Day __________
   Height of Lift __________
   Hook __________ Magnet __________ Other __________
   Give Size & Weight of Magnet or any Attachment

   Trolley:
   Number Moves per Hour _____ Hours per Day _____ Speed __________ fpm
   Average Movement __________ Ft.

   Bridge:
   Number Moves per Hour _____ Hours per Day _____ Avg. Movement __________ Ft.

7. Furnish complete information regarding special conditions such as acid fumes, steam, high temperatures, high altitudes, excessive dust or moisture, very sever duty, special or fine load handling.

   ____

   ____

8. Ambient Temperature in Building: Max.: __________ Min.: __________

9. Material Handled ______________________

10. Speeds Required: Hoist _______ fpm. Bridge _______ fpm. Trolley _______ fpm.

11. Crane to Operate: Indoors __________ Outdoors __________ Both __________

12. Current: Volts __________ Phase _______ Hertz __________ AC Volts __________ DC

13. Method of Control: Cab ____________ Floor ____________ Remote ____________

14. Location of Control: End of Crane ________ Center ____________ On Trolley ________
Other ____

15. Type of Control: (Give complete information including No. of speed points).
Full Magnetic ____________ Static ____________ Other ____________________

16. Type of Control Enclosure: ____

17. Type of Motors: (Give complete information) ____
____
____

18. Must wiring comply with Special Conditions or Codes
Describe briefly (See items 7 and 8)
____

19. Are Runway Conductors to be included

Type: Loose Wires ____________ Rigid Wires ____________ Angles ____________

Insulated (Mnfr.) ______________ Other ______________________________

20. List of Special Equipment if Accessories Desired ____
____
____

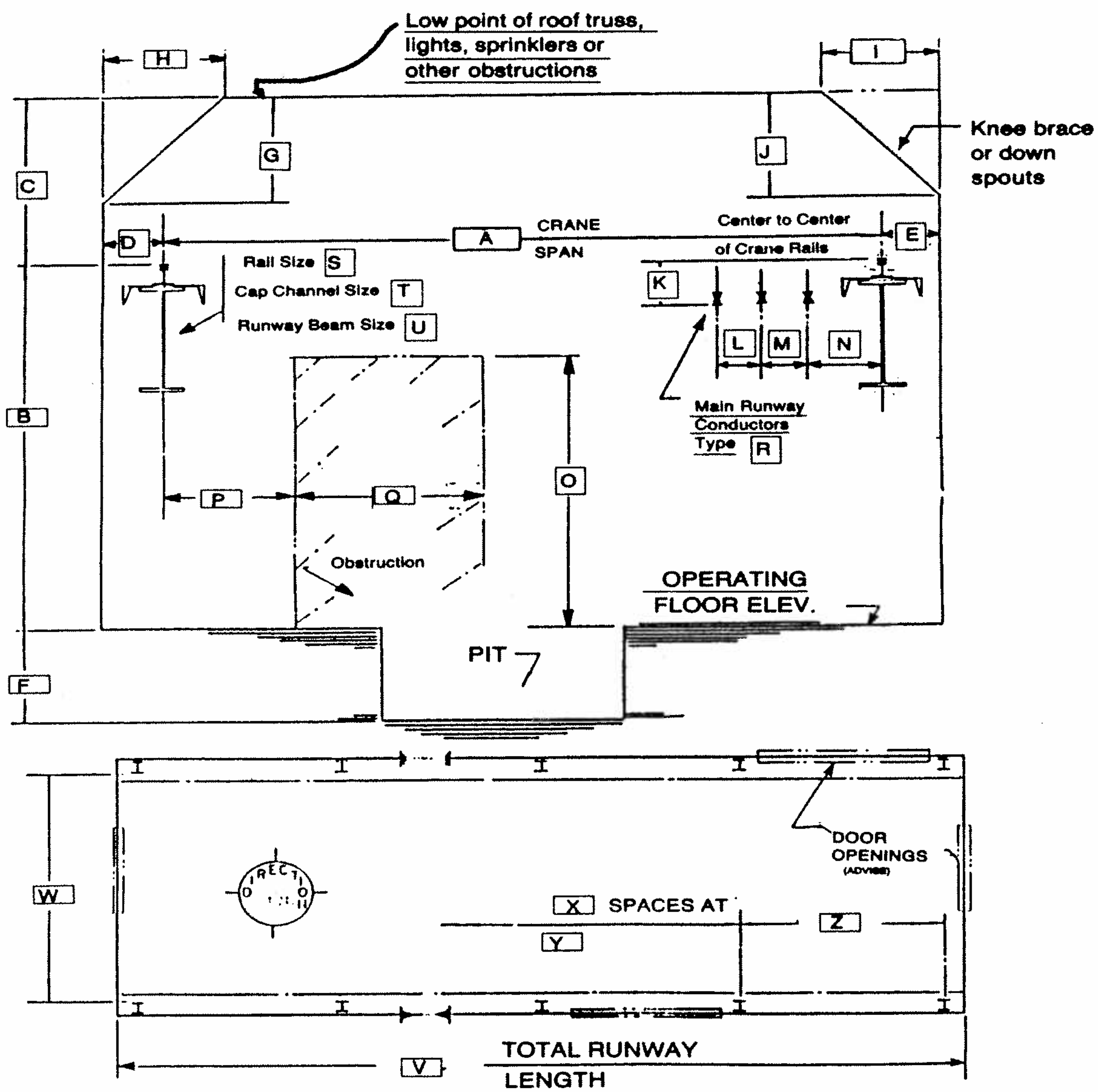
21. Specify when double hook cranes, double trolley cranes or special cranes are required giving detailed information on hook spacing, etc. ____
____

22. Complete attached building clearance drawing, making special note of any obstructions which may interfere with the crane, including special clearance conditions underneath the girders or cab.

CRANE INQUIRY DATA SHEET

BUILDING CLEARANCES
FOR TOP RUNNING SINGLE GIRDER CRANES

BUILDING CLEARANCES
FOR TOP RUNNING SINGLE GIRDER CRANES

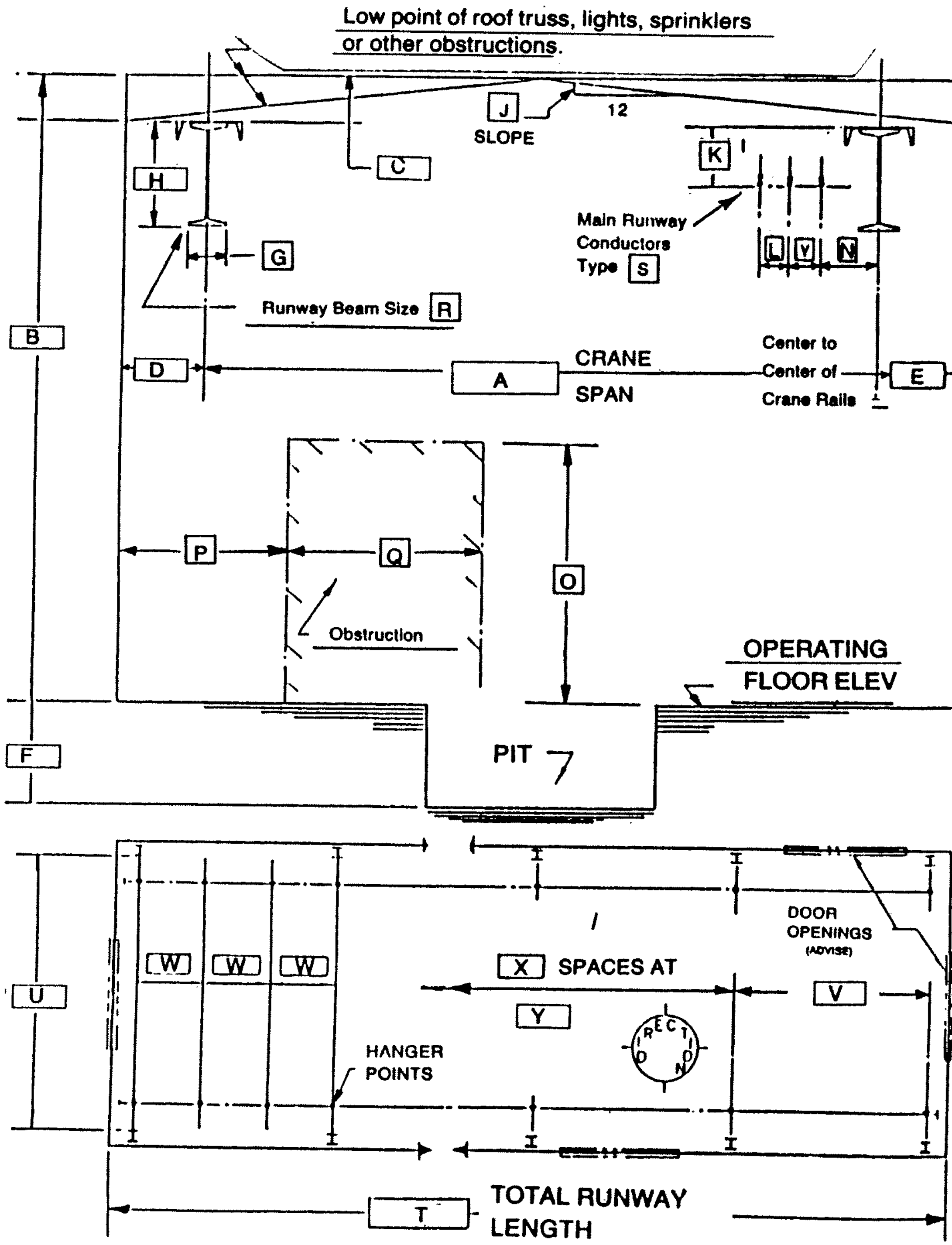


A	______	**E**	______	**I**	______	**Q**	______	**U**	______	**Y**	______
B	______	**F**	______	**J**	______	**R**	______	**V**	______	**Z**	______
C	______	**G**	______	**K**	______	**S**	______	**W**	______		
D	______	**H**	______	**L**	______	**T**	______	**X**	______		

A	______	E	______	I	______	M	______	Q	______	U	______	Y	______
B	______	F	______	J	______	N	______	R	______	V	______	Z	______
C	______	G	______	K	______	O	______	S	______	W	______		
D	______	H	______	L	______	P	______	T	______	X	______		

CRANE INQUIRY DATA SHEET

BUILDING CLEARANCES
FOR UNDER RUNNING SINGLE GIRDER CRANES



A ______	E ______	I ______	N ______	R ______	V ______
B ______	F ______	J ______	O ______	S ______	W ______
C ______	G ______	K ______	P ______	T ______	X ______
D ______	H ______	L ______	Q ______	U ______	Y ______

FIGURE 6.2

SUGGESTED OPERATING SPEEDS
FEET PER MINUTE
FLOOR CONTROLLED CRANES

CAPACITY IN TONS	HOIST			TROLLEY			BRIDGE		
	SLOW	MEDIUM	FAST	SLOW	MEDIUM	FAST	SLOW	MEDIUM	FAST
3	14	35	45	50	80	125	50	115	175
5	14	27	40	50	80	125	50	115	175
7.5	13	27	38	50	80	125	50	115	175
10	13	21	35	50	80	125	50	115	175
15	13	19	31	50	80	125	50	115	175
20	10	17	30	50	80	125	50	115	175
25	8	14	29	50	80	125	50	115	175
30	7	14	28	50	80	125	50	115	150

74-7 GLOSSARY

AUXILIARY GIRDER (OUTRIGGER): A girder arranged parallel to the main girder for supporting the platform motor base, operator's cab control panels, etc., to reduce the torsional forces such load would otherwise impose on the main girder.

BEARING LIFE EXPECTANCY: The L_{10} life of an antifriction bearing is the minimum expected life, in hours, of 90% of a group of bearings which are operating at a given speed and loading. The average expected life of the bearings is approximately five times the L_{10} life.

BOX SECTION: The rectangular cross section of girders, trucks or other members enclosed on four sides.

BRAKE: A device for retarding or stopping motion by friction or power means.

BRIDGE: That part of an overhead crane consisting of girder(s), trucks, walkway, and drive mechanism which carries the trolley and travels in a direction parallel to the runway.

BRIDGE CONDUCTORS: The electrical conductors located along the bridge structure of a crane to provide power to the trolley.

BUMPERS (BUFFER): An energy absorbing device for reducing impact when a moving crane or trolley reaches the end of its permitted travel; or when two moving cranes or trolleys come into contact.

CAB-OPERATED CRANE: A crane controlled by an operator in a cab located on the bridge or trolley.

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

CAPACITY: The maximum rated load (in tons) which a crane is designed to carry.

CLEARANCE: Minimum distance from the extremity of a crane to the nearest obstruction.

CMAA: Crane Manufacturers Association of America, Inc. (formerly EOCI - Electric Overhead Crane Institute).

COLLECTORS: Contacting devices for collecting current from the runway or bridge conductors. The mainline collectors are mounted on the bridge to transmit current from the runway conductors, and the trolley collectors are mounted on the trolley to transmit current from the bridge conductors.

CONTACTOR, MAGNETIC: An electromagnetic device for repeatedly establishing and interrupting an electric power circuit.

CONTROLLER: A device for regulating in a predetermined way the power delivered to a motor or other equipment.

COVER PLATE: The top and bottom plate of a box girder.

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

DEAD LOADS: The loads on a structure which remain in a fixed position relative to the structure. On a crane bridge such loads include the girders, footwalk, cross shaft, drive units, panels, etc.

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

DIAPHRAGM: A plate or partition between opposite parts of a member, serving a definite purpose in the structural design of a member.

DUMMY CAB: An operator's compartment or platform on a pendant or radio controlled crane, having no permanently mounted electrical controls, in which an operator may ride while controlling the crane, from a pendant or remote control station.

ELECTRIC OVERHEAD TRAVELING CRANE: An electrically operated machine for lifting, lowering and transporting loads, consisting of a movable bridge carrying a fixed or movable hoisting mechanism and traveling on an overhead runway structure.

ELECTRICAL BRAKING SYSTEM: A method of controlling crane motor speed when in an overhauling condition, without the use of friction braking.

ENCLOSED CONDUCTOR(S): A conductor or group of conductors substantially enclosed to prevent accidental contact.

ENCLOSURE: A housing to contain electrical components, usually specified by a NEMA classification number.

END APPROACH: The minimum horizontal distance, parallel to the runway, between the outermost extremities of the crane and the centerline of the hook.

END TRUCK: The unit consisting of truck frame, wheels, bearings, axles, etc., which supports the bridge girder.

FIELD WIRING: The wiring required after erection of the crane.

FIXED AXLE: An axle which is fixed in the truck and on which the wheel revolves.

FLOOR OPERATED CRANE: A crane which is pendant controlled by an operator on the floor or on an independent platform.

FOOTWALK: The walkway with handrail and toeboards, attached to the bridge for access purposes.

GIRDER: The principal horizontal beam of the crane bridge which supports the trolley and is supported by the end trucks.

HOIST: A machinery unit that is used for lifting and lowering a load.

HOLDING BRAKE: A brake that automatically prevents motion when power is off.

HOOK APPROACH: The minimum horizontal distance between the center of the runway rail and the hook.

INTERLOCKING CRANE: A crane equipped with a device to hold alignment between the crane girder and a spur or another crane girder.

INVERTER (VARIABLE FREQUENCY DRIVE): A method of control by which the fixed line voltage and frequency is changed to a three-phase system with infinitely variable voltage and frequency.

ksi: Kips per square inch - measurement of stress intensity.

KIP: A unit of force equivalent to 1000 pounds.

KNEE BRACE: The diagonal structural member joining the building column and roof truss.

LIFT: Maximum safe vertical distance through which the hook, magnet or bucket can move.

LIFTING DEVICES: Buckets, magnets, grabs, and other supplemental devices, the weight of which is to be considered part of the rated load, used for ease in handling certain types of loads.

LIMIT SWITCH: A device designed to cut off the power automatically at or near the limit of travel for the crane motion.

LINE CONTACTOR: A contactor to disconnect power from the supply lines.

LIVE LOAD: A load which moves relative to the structure under consideration.

LOAD CARRYING PART: Any part of the crane in which the induced stress is influenced by the load on the hook.

MAGNETIC CONTROL: A device or system of devices having all basic functions operated by electromagnets.

MAIN LINE CONTACTOR: A magnetic contactor used in the incoming power circuit from the mainline collectors.

MAIN LINE DISCONNECT: A manual switch which breaks the power lines leading from the main line collectors.

MASTER SWITCH: A manually operated device which serves to govern the operation of contactors and auxiliary devices of an electric control.

MATCH MARKING: Identification of non-interchangeable parts for reassembly after shipment.

OPERATORS CAB: The operator's compartment from which movements of the crane are controlled.

OVERLOAD PROTECTION (OVERCURRENT): A device operative on excessive current to cause and maintain the interruption or reduction of current flow to the equipment governed.

PATENTED TRACK: A generic term referring to crane and monorail equipment built in accordance with the MMA specification utilizing a composite track section incorporating a proprietary bottom flange shape.

PENDANT PUSHBUTTON STATION: Means suspended from the crane for operating the controllers from the floor or other level beneath the crane.

PLAIN REVERSING CONTROL: A reversing control which has identical characteristics for both directions of motor rotation.

PROTECTIVE PANEL: An assembly containing overload and undervoltage protection for all crane motions.

RAIL SWEEP: A device attached to the truck and located in front of the truck's leading wheels to remove obstructions.

RATED LOAD: The maximum load which the crane is designed to handle safely.

RESISTOR RATING: Rating established by NEMA which classifies resistor according to percent of full load current on first point and duty cycle.

ROTATING AXLE: An axle which rotates with the wheel.

RUNWAY: The rails, beams, brackets and framework on which the crane operates.

RUNWAY CONDUCTORS: The main conductors mounted on or parallel to the runway which supply current to the crane.

RUNWAY RAIL: The rail supported by the runway beams on which the bridge travels.

"S" SECTION: A standard beam shape as defined by the American Institute of Steel Construction.

SAFETY LUG: A mechanical device fixed securely to the end truck or trolley yoke which will limit the fall of the crane or carrier in case of wheel or axle failure.

SHALL: This word indicates that the adherence to the particular requirement is necessary in order to conform to the specification.

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

SINGLE GIRDER CRANE: An electric overhead traveling crane having one main girder which supports a fixed hoist or a hoist mounted on an underrunning trolley. An auxiliary girder may be provided to reduce the torsional stresses on the main girder.

SPAN: The horizontal distance center-to-center of runway rails or beams.

STATIC CONTROL: A method of switching electrical circuits without the use of contacts.

STEPPED: A type of control system with three or more speed points.

STOP: A device to limit travel of a trolley or crane bridge. This device normally is attached to a fixed structure and normally does not have energy absorbing ability.

STRENGTH, AVERAGE ULTIMATE: The average tensile force per unit of cross sectional area required to rupture the material as determined by test.

STRESS: Load or force per unit area tending to deform the material usually expressed in pound per square inch.

SWEEP: Maximum lateral deviation from straightness of structural member, measured at right angles to the Y-Y axis.

TOP RUNNING CRANE: An electric overhead traveling crane having the end trucks supported on rails attached to the top of the crane runway.

TORQUE, FULL LOAD (MOTOR): The torque produced by a motor at its rated horsepower and speed.

UNDER RUNNING CRANE: An electric overhead traveling crane having the end trucks supported on track attached to the bottom flanges of the beams; or supported on bottom flanges of beams. These beams make up the crane runway.

UNDER VOLTAGE PROTECTION: A device operative on the reduction or failure of voltage to cause and maintain the interruption of power in the main circuit.

VARIABLE FREQUENCY: A method of control by which the motor supply voltage and frequency can be adjusted.

VOLTAGE DROP: The loss of voltage in an electric conductor between supply tap and load tap.

W SECTION: A wide flange beam shape as defined by the American Institute of Steel Construction.

WEB PLATE: The vertical plate connection the upper and lower flanges or cover plates of a girder.

WHEEL BASE: Distance from center to center of outermost wheels.

WHEEL LOAD: The load without vertical inertia forces on any wheel with the trolley and lifted load (rated capacity) positioned on the bridge to give maximum loading.

- NOTES -

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5M 3/94
3M 7/99 PBM
2M 1/04 PBM