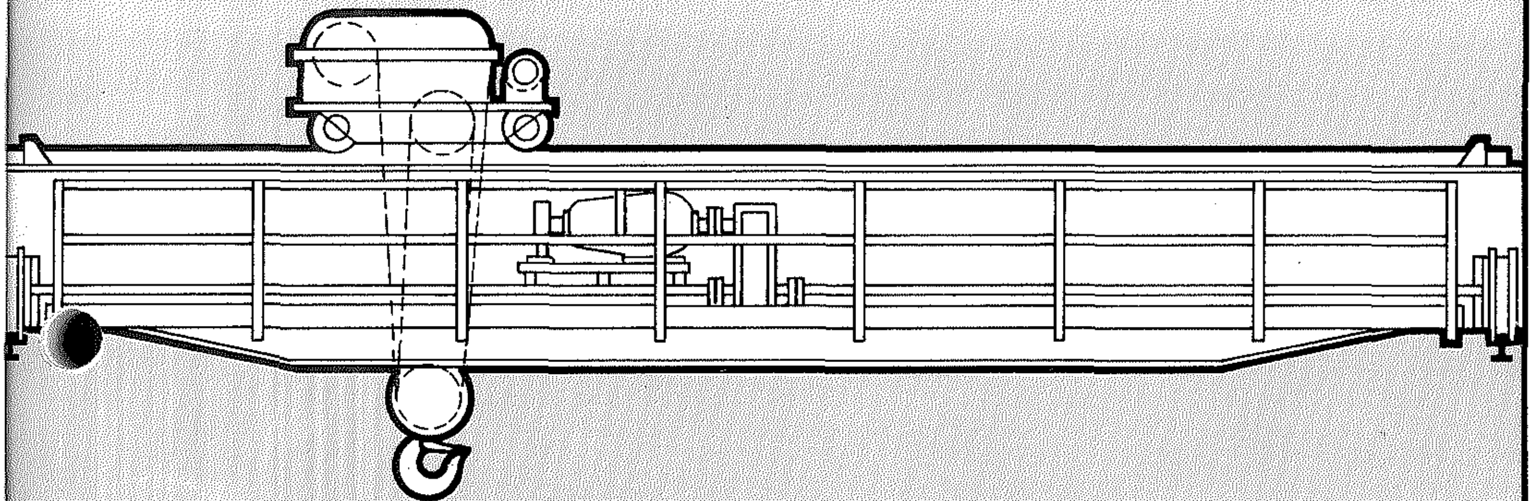
CRANE MANUFACTURERS
ASSOCIATION OF AMERICA, INC.

Specifications for Electric Overhead Traveling Cranes

**Prepared by
Crane Manufacturers Association
of America, Inc.**



CMAA Specification #70, Revised 1988
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C.M.A.A. SPECIFICATION NO. 70-1983
SPECIFICATIONS FOR ELECTRIC OVERHEAD TRAVELING CRANES

INTRODUCTION

This specification has been developed by the Crane Manufacturers Association of America, Inc. [C.M.A.A.], 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:

DISCLAIMER

Users should rely on their own engineers/designers or a manufacturer representative to specify or design applications or uses. Whenever a user refers to all or any part of this specification to place an order, mandatory language imposing requirements in the specification is intended as the user's voluntary acceptance of those specifications for that order.

The voluntary use of these specifications is not intended to, and does not in any way, limit the ingenuity or prerogative of individual manufacturers to design or produce electric overhead traveling cranes which do not comply with these specifications. Rather, these specifications provide technical guidelines for the user to specify his application. Following these specifications does not assure compliance with applicable federal, state, or local regulations and codes which must be referenced in each instance.

These specifications are not binding on any person and do not have the effect of law, and CMAA assumes no responsibility and disclaims all liability of any kind, however arising, as a result of acceptance or use of these specifications.

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70-1 GENERAL SPECIFICATIONS

1.1 SCOPE

1.1.1 This specification shall be known as the Specifications for Electric Overhead Traveling Cranes - C.M.A.A. Specification No. 70 - Revised 1983.

1.1.2 The specifications and information contained in this publication apply to top running bridge and gantry type multiple girder electric overhead traveling cranes. It should be understood that the specifications are general in nature and other specifications may be agreed upon between the purchaser and the manufacturer to suit each specific installation. C.M.A.A. Specification No. 74 covers top running and under running single girder overhead traveling cranes. Later specifications will cover cranes of the stacker and other special purpose or special application types. These specifications do not cover equipment used to lift, lower, or transport personnel suspended from the hoist rope system.

1.1.3 This specification outlines in Section 70-2 six different classes of crane service as a guide for determining the service requirements of the individual application. In many cases there is no clear category of service in which a particular crane operation may fall, and the proper selection of a crane can be made only through a discussion of service requirements and crane details with the crane manufacturer or other qualified persons.

1.1.4 Service conditions have an important influence on the life of the wearing parts of a crane, such as wheels, gears, bearings, wire rope, electrical equipment and must be considered in specifying a crane to assure maximum life and minimum maintenance.

1.1.5 In selecting overhead crane equipment, it is important that not only present but future operations be considered which may increase loading and service requirements and that equipment be selected which will satisfy future increased service conditions, thereby minimizing the possibility of overloading or placing in a duty classification higher than intended.

1.1.6 Parts of this specification refer to certain portions of other applicable specifications, codes or standards. Where interpretations differ, C.M.A.A. recommends that this specification be used as the guideline. Mentioned in the text are publications of the following organizations.

AGMA - American Gear Manufacturers Assn.
1901 North Ft. Meyer Drive
Arlington, Virginia 22209

210.02-1965 - Surface Durability (Pitting) of Spur Gear Teeth

211.02-1969 - Surface Durability (Pitting) of Helical and Herringbone Gear Teeth

220.02-1966 - Rating the Strength of Spur Gear Teeth

221.02-1965 - Rating the Strength of Helical and Herrington Gear Teeth

AISC - American Institute of Steel Construction
400 North Michigan Avenue
Chicago, Illinois 60611

ANSI - American National Standards Institute
1430 Broadway
New York, New York 10018

A58.1-1971 - Building Code Requirements for Minimum Design Loads in Buildings and Other Structures

B30.2.0-1976 - Overhead & Gantry Cranes (Top Running Bridge, Multiple Girder)

ASME - The American Society of Mechanical Engineers
345 East 47th Street, N.W.
New York, New York 10017

ASTM - American Society for Testing & Materials
1916 Race Street
Philadelphia, Pennsylvania 19013

AWS - American Welding Society
550 N. LeJeune Road
Miami, Florida 33126

D14.1-85 Specification for Welding of Industrial and Mill Cranes

CMAA - Crane Manufacturers Association of America, Inc.
8720 Red Oak Blvd., Suite 201
Charlotte, North Carolina 28217

Overhead Crane Inspection and Maintenance Checklist

Crane Operators Manual

NEC - National Electrical Code
National Fire Protection Association
470 Atlantic Avenue
Boston, Massachusetts 02210

NFPA 70-1981 National Electric Code

NEMA - National Electrical Manufacturers Assn.
2101 "L" Street, N.W.
Washington, D.C. 20037

ICS1-1978 NEMA Standards

OSHA - Office of Safety & Health Standards
U.S. Department of Labor
Washington, D.C. 20210

OSHA 2206-1976 General Industry Standards

Stress Concentration Factors
R.E. Peterson
Copyright, 1974
John Wiley & Sons, Inc.

Data was utilized from (FEM) Federation Europeenne De La Manutention, Section I Heavy Lifting Equipment, Rules for the Design of Hoisting Appliances, 2nd Edition - December 1970.

1.2 BUILDING DESIGN CONSIDERATIONS

1.2.1 The building in which an overhead crane is to be installed must be designed with consideration given to the following points:

1.2.1.1 The distance from the floor to the lowest overhead obstruction must be such as to allow for the required hook lift plus the distance from the saddle or palm of the hook in its highest position to the high point on the crane plus clearance to the lowest overhead obstruction.

1.2.1.2 In addition, the distance from the floor to the lowest overhead obstruction must be such that the lowest point on the crane will clear all machinery or when necessary provide railroad 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 (304.8 mm). Fixed ladder shall be in conformance with ANSI safety code for fixed ladders, A 14.3.

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.

1.3.2 The clearance between the end of the crane and the building columns, knee braces or any other obstructions 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

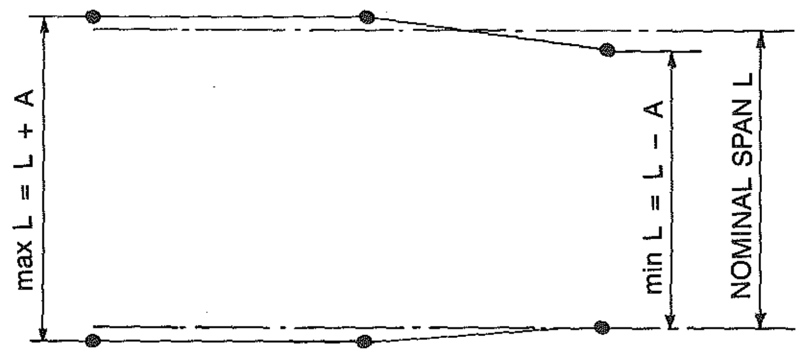
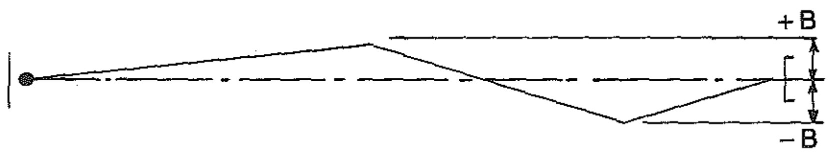
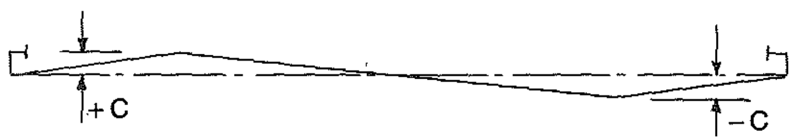
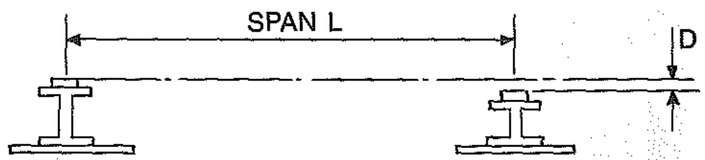
1.4.1 The crane runway, runway rails, and crane stops are typically furnished by the purchaser unless otherwise specified. The crane stops furnished by the purchaser are to be designed to suit the specific crane to be installed.

1.4.2 The runway rails shall be straight, parallel, level and at the same elevation. The distance, center to center, and the elevation shall be within the tolerances given in Table 1.4.2-1. The runway rails should be standard rail sections or any other commercial rolled sections with equivalent specifications of a proper size for the crane to be installed and must be provided with proper rail splices and hold-down fasteners. Rail separation at joint should not exceed $1/32$ inch. Floating rails are not recommended.

1.4.3 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/400 based on 10 percent of maximum wheel load(s) without impact. The vertical deflection should not exceed L/600 based on maximum wheel load(s) without impact. Gantry and other types of special cranes may require additional considerations.

TABLE 1.4.2-1

ITEM	FIGURE	OVERALL TOLERANCE	MAXIMUM RATE OF CHANGE
SPAN		L≤50′ A = 3⁄16″ L>50′≤100′ A = 1⁄4″ L>100′ A = 3⁄8″	1⁄4″ IN 20′-0″
STRAIGHTNESS		B = 3⁄8″	1⁄4″ IN 20′-0″
ELEVATION		C = 3⁄8″	1⁄4″ IN 20′-0″
RAIL-TO-RAIL ELEVATION		L≤50′ D = ± 3⁄16″ L>50′≤100′ D = ± 1⁄4″ L>100′ D = ± 3⁄8″	1⁄4″ IN 20′-0″

1.5 RUNWAY CONDUCTORS

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

1.5.2 Contact conductors shall be guarded in a manner that persons cannot inadvertently touch energized current - carrying parts. Flexible conductor systems shall be designed and installed in a manner to minimize the effects of flexing, cable tension, and abrasion

1.5.3 Runway conductors are normally furnished and installed by the purchaser unless otherwise specified.

1.5.4 The conductors shall be properly supported and aligned horizontally and vertically with the runway rail.

1.5.5 The conductors shall have sufficient ampacity to carry the required current to the crane, or cranes, when operating with rated load. The conductor ratings shall be selected in accordance with Article 610 of the National Electrical Code. For manufactured conductor systems with published ampacities, the intermittent ratings may be used. The ampacities of fixed loads such as heating, lighting, and air conditioning may be computed as 2.25 times their sum total which will permit the application of the intermittent ampacity ratings for use with continuous fixed loads.

1.5.6 The nominal runway conductor supply system voltage, actual input tap voltage, and runway conductor voltage drops shall result in crane motor voltage tolerances per Section 5.13 (Voltage Drops).

1.5.7 In a crane inquiry the runway conductor system type should be specified and if 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 is specified by the manufacturer. This capacity shall be marked on each side of the crane and shall be legible from the operating floor.

1.6.2 The rated capacity of a crane bridge with multiple hoist units is the rated capacity of the maximum individual hoist unit. Each individual hoist unit shall have its rated capacity marked on its bottom block.

1.6.3 When determining the rated capacity of a crane, all accessories below the hook, such as load bars, magnets, grabs, etc. shall be included as part of the load to be handled.

1.7 DESIGN STRESSES

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

Structural parts shall be designed according to the appropriate limits as per chapter 70-3 of this specification. Mechanical parts shall be designed according to Chapter 70-4 of this specification. All other load carrying parts shall be designed so that the calculated static stress in the material, based on rated crane capacity, shall not exceed 20 percent of the published average ultimate strength of the material.

This limitation of stress provides a margin of strength to allow for variations in the properties of materials, manufacturing and operating conditions, and design assumptions, and under no condition should imply authorization or protection for users loading the crane beyond rated capacity.

1.8 GENERAL

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

1.8.2 This specification includes all applicable features of OSHA Section 1910.179 - Overhead and Gantry Cranes, and ANSI B30.2.0—Safety Standard for Overhead and Gantry Cranes.

1.9 PAINTING

1.9.1 Before shipment, the crane shall be cleaned and given a protective coating.

1.9.2 The coating may consist of any number of coats of primer and finish paint according to the manufacturer's standard or as otherwise specified.

1.10 ASSEMBLY AND PREPARATION FOR SHIPMENT

1.10.1 The crane should be assembled in the manufacturer's plant according to the manufacturer's standard. When feasible, the trolley should be placed on the assembled crane bridge, but it is not required to reeve the hoisting rope.

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 non-destructive 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

1.12.1 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 sets of operating instructions and spare parts information are typically furnished. Detail drawings are normally not furnished.

1.13 ERECTION

1.13.1 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

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

1.15 INSPECTION, MAINTENANCE AND CRANE OPERATOR

1.15.1 For inspection and maintenance of cranes, refer to applicable section of ANSI B30.2.0, Chapter 2-2, and CMAA-Overhead Crane Inspection and Maintenance Checklist.

1.15.2 For operator responsibility and training, refer to applicable section of ANSI B30.2.0, Chapter 2-3, and CMAA-Crane Operators Manual.

70-2 CRANE CLASSIFICATIONS

2.1 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.

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

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

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

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

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 (−17.7° 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 two to five lifts per hour, averaging ten feet per lift.

2.4 CLASS C (MODERATE SERVICE)

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

2.6 CLASS E (SEVERE SERVICE)

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

2.7 CLASS F (CONTINUOUS SEVERE SERVICE)

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

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

The definition of CMAA crane service class in terms of load class and load cycles is shown in Table 2.8-1.

TABLE 2.8-1

DEFINITION OF CMAA CRANE SERVICE CLASS IN TERMS OF LOAD CLASS AND LOAD CYCLES

LOAD CLASS	Load Cycles				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	E	0.531-0.67
L_3	C	D	E	F	0.671-0.85
L_4	D	E	F	F	0.851-1.00
	Irregular occasional use followed by long idle periods	Regular use in intermittent operation	Regular use in continuous operation	Regular use in severe continuous operation	

LOAD CLASSES:

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 one third of the rated load.

L_3 = Cranes which hoist the rated load fairly frequently and normally, loads between ⅓ and ⅔ of the rated load.

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

LOAD CYCLES:

N_1 = 20,000 to 200,000 cycles

N_2 = 200,000 to 600,000 cycles

N_3 = 600,000 to 2,000,000 cycles

N_4 = Over 2,000,000 cycles

70-3 STRUCTURAL DESIGN:

3.1 MATERIAL

All structural steel used 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 of Industrial and Mill Cranes and other Overhead Material Handling Equipment," with the exception of Section 705 which shall be in accordance with the Crane Manufacturer's Standard Tolerance for deviation from specified camber and sweep, with all such measurements taken at the manufacturer's plant prior to shipment. Base weld stresses applicable to load combination Case 1, Section 3.3.2.4.1.

3.3 STRUCTURE

3.3.1 General

The crane girders shall be welded structural steel box sections, wide flange beams, standard I-beams, reinforced beams or sections fabricated from structural plates and shapes. The manufacturer shall specify the type and the construction to be furnished.

3.3.2 Loadings

3.3.2.1 The crane structures are subjected in service to repeated loading varying with time which induce variable stresses in members and connections through the interaction of the structural system and the cross-sectional shapes. The loads acting on the structure are divided into three different categories. All of the loads having an influence on engineering strength analysis are regarded as principal loads, namely the dead loads, which are always present; the hoist load, acting during each cycle; and the inertia forces acting during the movements of cranes, crane components, and hoist loads. Load effects, such as operating wind loads, skewing forces, snow loads, temperature effect, loads on walkways, stairways, platforms and handrails are classed 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.

3.3.2.1.1 Principal Loads

3.3.2.1.1.1 Dead Load (DL)

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

3.3.2.1.1.2 Trolley Load (TL)

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

3.3.2.1.1.3 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.

3.3.2.1.1.4 Vertical Inertia Forces (VIF)

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

3.3.2.1.1.4.1 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 Table 3.3.2.1.1.4.1-1.

TABLE 3.3.2.1.1.4.1-1

TRAVEL SPEED (FPM)	DEAD LOAD FACTOR (DLF)
UP TO 200	1.1
OVER 200	1.2

3.3.2.1.1.4.2 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 impact value shall be taken as 50 percent of the rated capacity of the bucket or magnet hoist.
$(HLF) = .15 \leqslant .005 \text{ (hoist speed)} \leqslant .5$

3.3.2.1.1.5 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 acceleration or deceleration rate (FT/SEC^2) but not less than 2.5 percent of the vertical load. This percentage shall be applied to both the live and dead loads, exclusive of the endtrucks and end ties. The live load shall be located in the same position as when calculating the vertical moment. The lateral load shall be equally divided between the two girders, and 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.

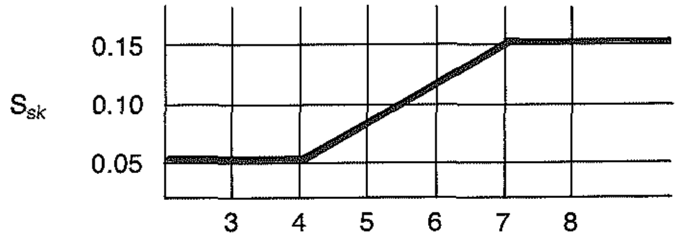
3.3.2.1.2 Additional Loads:

3.3.2.1.2.1 Operating Wind Load (WLO)

Unless otherwise specified, the lateral load due to wind on outdoor cranes shall be considered as 5 pounds per square foot of projected area exposed to the wind. The wind load on the trolley shall be considered as equally divided between the two girders. Where multiple surfaces are exposed to the wind, such as bridge girders where the horizontal distance between the surfaces is greater than the depth of a girder, a wind area shall be considered to be 1.6 times the projected area of one girder. For single surfaces such as cabs or machinery enclosures, a wind area shall be considered to be 1.2 times the projected area to account for negative pressure on the far side of the enclosure.

3.3.2.1.2.2 **Forces Due to Skewing (SK)**

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



$$\text{RATIO} = \frac{\text{SPAN}}{\text{WHEELBASE}}$$

3.3.2.1.3 **Extraordinary Loads:**

3.3.2.1.3.1 **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 ANSI A58.1).

3.3.2.1.3.2 **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 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 M1, M2, and a 40 percent maximum traveling speed of V_{T1} and V_{T2} shall be determined from the following equation:

$$E = \frac{M_1M_2\,(.4V_{T1} + .4V_{T2})^2}{2(M_1 + M_2)}$$

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.

3.3.2.2 **Torsional Forces and Moments**

3.3.2.2.1 **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.

3.3.2.2.2 **Due to Vertical Loads:**

3.3.2.2.2.1 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.

3.3.2.2.3 Due to Lateral Loads:

3.3.2.2.3.1 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.

3.3.2.3 Longitudinal Distribution of the Wheel Load

Local stresses in the rail, rail base, flanges, welds, and in the web plate due to wheel load acting normal and transversely to the rail shall be determined in accordance with the rail and flange system. The individual wheel load can be uniformly distributed in the direction of the rail over a length of $S = 2(R + C) + 2$ in., provided that the rail is directly supported on the flange as shown in Figure 3.3.2.3-1.

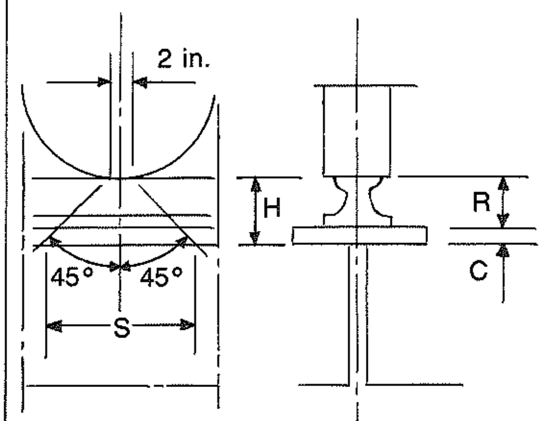


Fig. 3.3.2.3-1

where $H = R + C$

$S = 2H + 2 \text{ in.} = 2(R+C) + 2 \text{ in.}$

R = height of the rail

C = thickness of top cover plate

3.3.2.4 Load Combination

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

3.3.2.4.1 Case 1: Crane in regular use under principal loading (Stress Level 1)

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

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

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

3.3.2.4.3 Case 3: Extraordinary loads (Stress Level 3)

3.3.2.4.3.1 Crane subjected to out of service wind

$DL + TL + WLS$

3.3.2.4.3.2 Crane in collision

$DL + TL + LL + CF$

3.3.2.4.3.3 Test Loads

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

3.4 ALLOWABLE STRESSES

	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 exist, the reference stress σ_t can be calculated from the following formula:

$$\sigma_t = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2} \leqslant \sigma_{ALL.}$$

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

$$\sigma_V = \frac{1}{2}[\sigma_x + \sigma_y] \pm \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau^2} \leqslant \sigma_{ALL.}$$

3.4.5 Buckling Analysis

The analysis for proving safety against local buckling and 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 Cc:

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

$$\text{where: } C_c = \sqrt{\frac{2\pi^2 E}{\sigma_y}}$$

3.4.6.2 On the cross section of axially loaded compression members susceptible to buckling shall be calculated when KL/r exceeds Cc:

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

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

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

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

when $\frac{\sigma_a}{\sigma_A} \leqslant .15$ the following formula may be used

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

where:

K = effective length factor
L = unbraced length of compression member
r = radius of gyration of member
E = modulus of elasticity
$\sigma_{y,p}$ = 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
Cm_x, Cm_y = 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,

   $C_m = 0.6 - 0.4 \frac{M_1}{M_2}$, 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 Cm 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 Cm = 0.85

   b. For members whose ends are unrestrained Cm = 1.0

3.4.7 Allowable Stress Range - Repeated Load

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

TABLE 3.4.7-1

ALLOWABLE STRESS RANGE σ_{sr} - kips/inch^2

CMAA Service Class	JOINT CATEGORY					
	A	B	C	D	E	F
A	43	43	43	43	40	43
B	43	43	43	40	28	43
C	43	43	40	28	20	31
D	43	34	28	20	14	22
E	34	24	20	14	10	16
F	24	17	14	10	7	11

Stress range values are independent of material yield stress.

TABLE 3.4.7-2A

FATIGUE STRESS PROVISIONS - TENSION ("T") OR REVERSAL ("REV") 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 2½ with permanent backing bar parallel to the direction of stress when welds are ground and weld soundness established by nondestructive testing. Backing bar is to be continuous, and, if spliced, is to be joined by a full-penetration butt weld. Backing bar is to be connected to parent metal by continuous welds along both edges, except intermittent welds may be used in regions of compression stress.	B	19,20	T or Rev.
Groove Welded Connections	Base metal at details of any length attached by groove welds subjected to transverse or longitudinal loading, or both, when weld soundness transverse to the direction of stress is established by nondestructive testing and the detail embodies a transition radius, R, with the weld termination ground when.			
	Longitudinal Loading: (a) R x 24 in.	B	13	T or Rev.
	(b) 24 in. x R x 6 in.	C	13	T or Rev.
	(c) 6 in. x R x 2 in.	D	13	T or Rev.
	(d) 2 in. x R x 0	E	12,13	T or Rev.
	Traverse Loading: Materials having equal or unequal thickness sloped, welds ground web connections excluded. (a) R x 24 in.	B	13	T or Rev.
	(b) 24 in. x R x 6 in.	C	13	T or Rev.

TABLE 3.4.7-2A (Continued)

FATIGUE STRESS PROVISIONS - TENSION ("T") OR REVERSAL ("REV") STRESSES

GENERAL CONDITION	SITUATION	JOINT CATEGORY	EXAMPLE OF A SITUATION	KIND OF STRESS
	(c) 6 in. x R x 2 in.	D	13	T or Rev.
	(d) 2 in. x R x 0	E	12,13	T or Rev.
	Transverse Loading: Materials having equal thickness, not ground, web connections excluded.			
	(a) R x 24 in.	C	13	T or Rev.
	(b) 24 in. x R x 6 in.	C	13	T or Rev.
	(c) 6 in. x R x 2 in.	D	13	T or Rev.
	(d) 2 in. x R x 0	E	12,13	T or Rev.
	Transverse Loading: Materials having unequal thickness, not sloped or ground, including web connections			
	(a) R x 24 in.	E	13	T or Rev.
	(b) 24 in. x R x 6 in.	E	13	T or Rev.
	(c) 6 in. x R x 2 in.	E	13	T or Rev.
	(d) 2 in. x R x 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) x 2 in.	C	12,14,15, 16,18	T or Rev.
	(b) 2 in. x L x 4 in.	D	12,18	T or Rev.
	(c) L x 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 x 24 in.	B	13	T or Rev.
	(b) When 24 in. x R x 6 in.	C	13	T or Rev.
	(c) When 6 in. x R x 2 in.	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

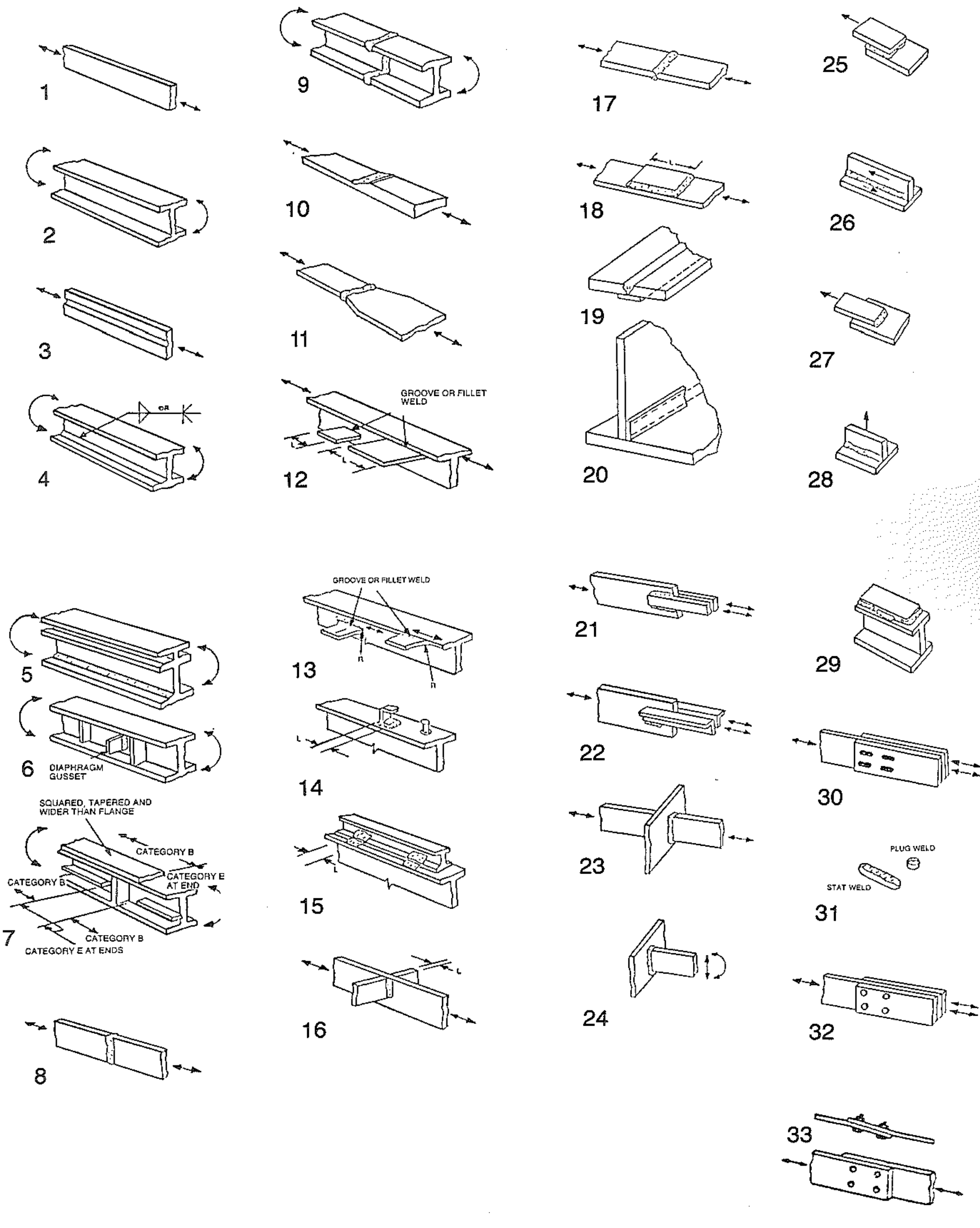


FIGURE NO. 3.4.7-3
FOR TYPICAL BOX GIRDER

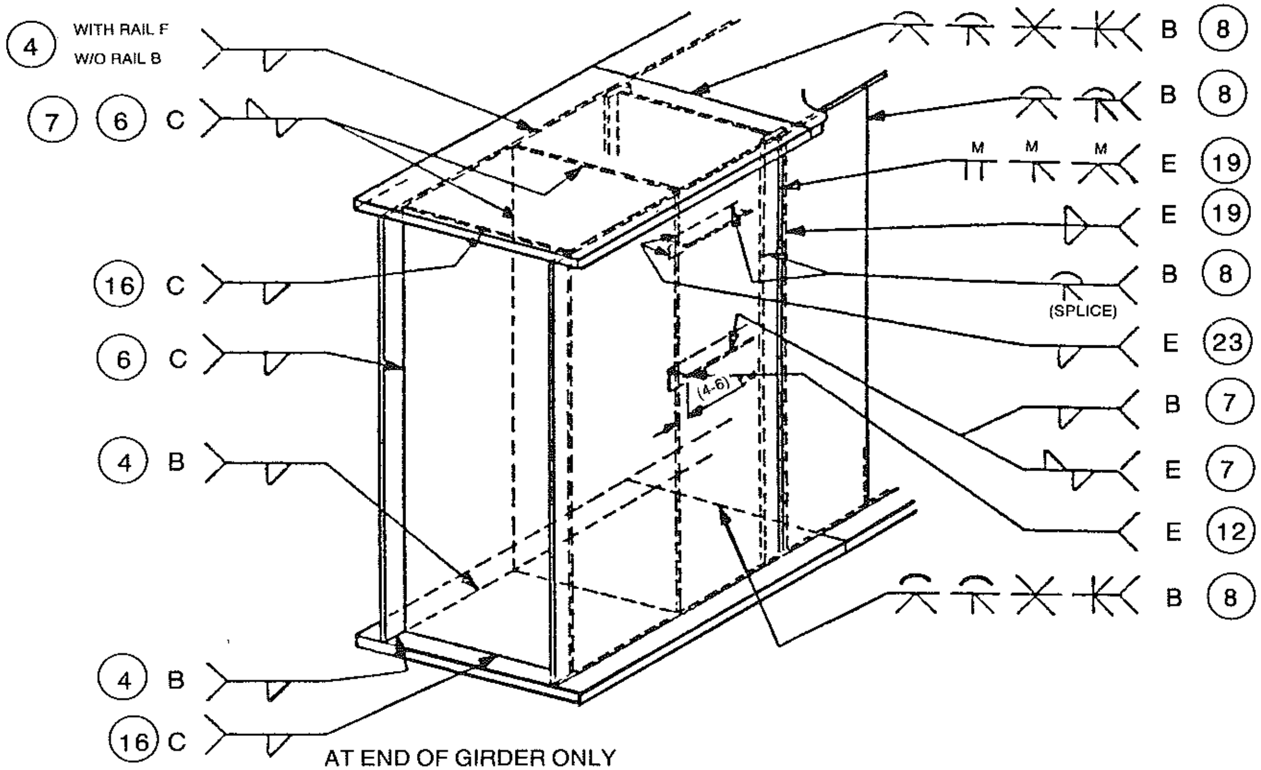
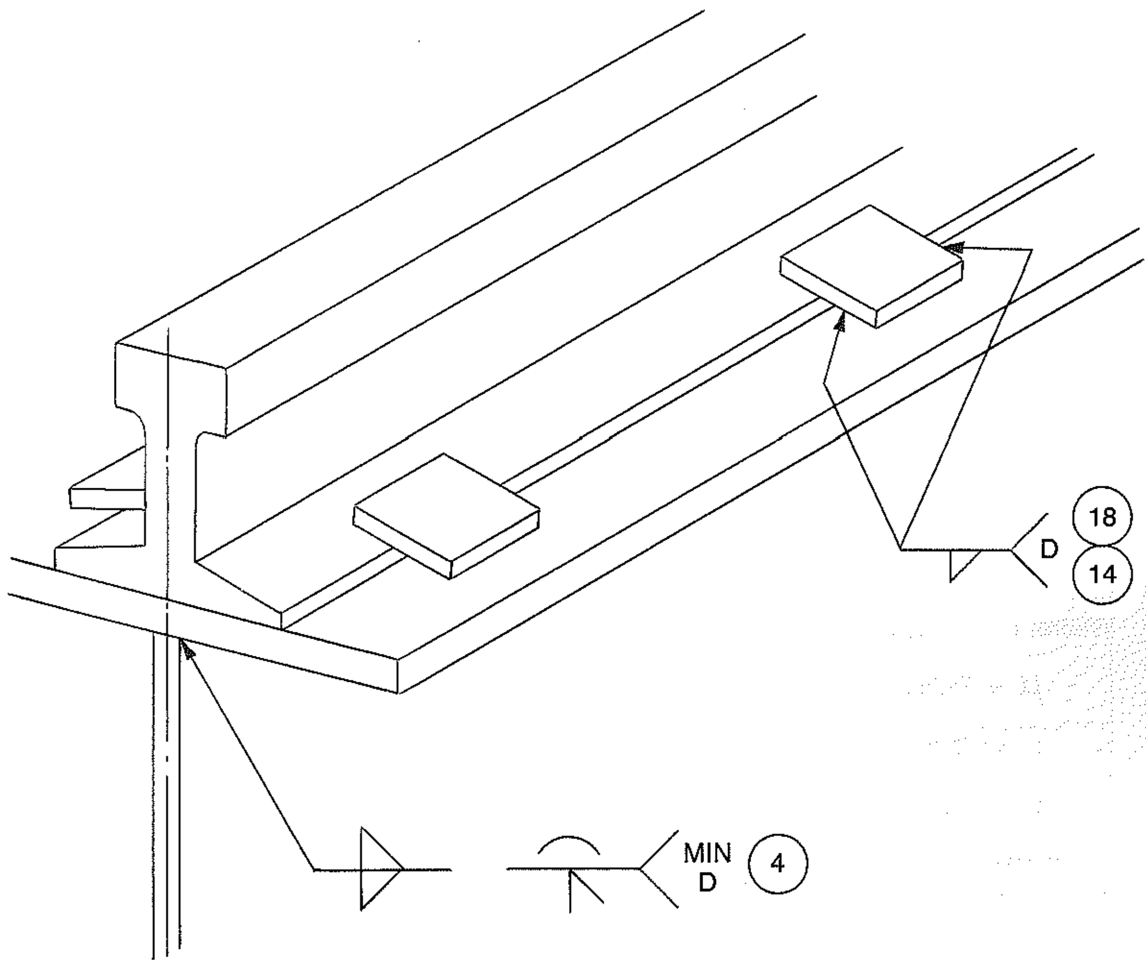


FIGURE NO. 3.4.7-4
FOR TYPICAL TROLLEY RAIL



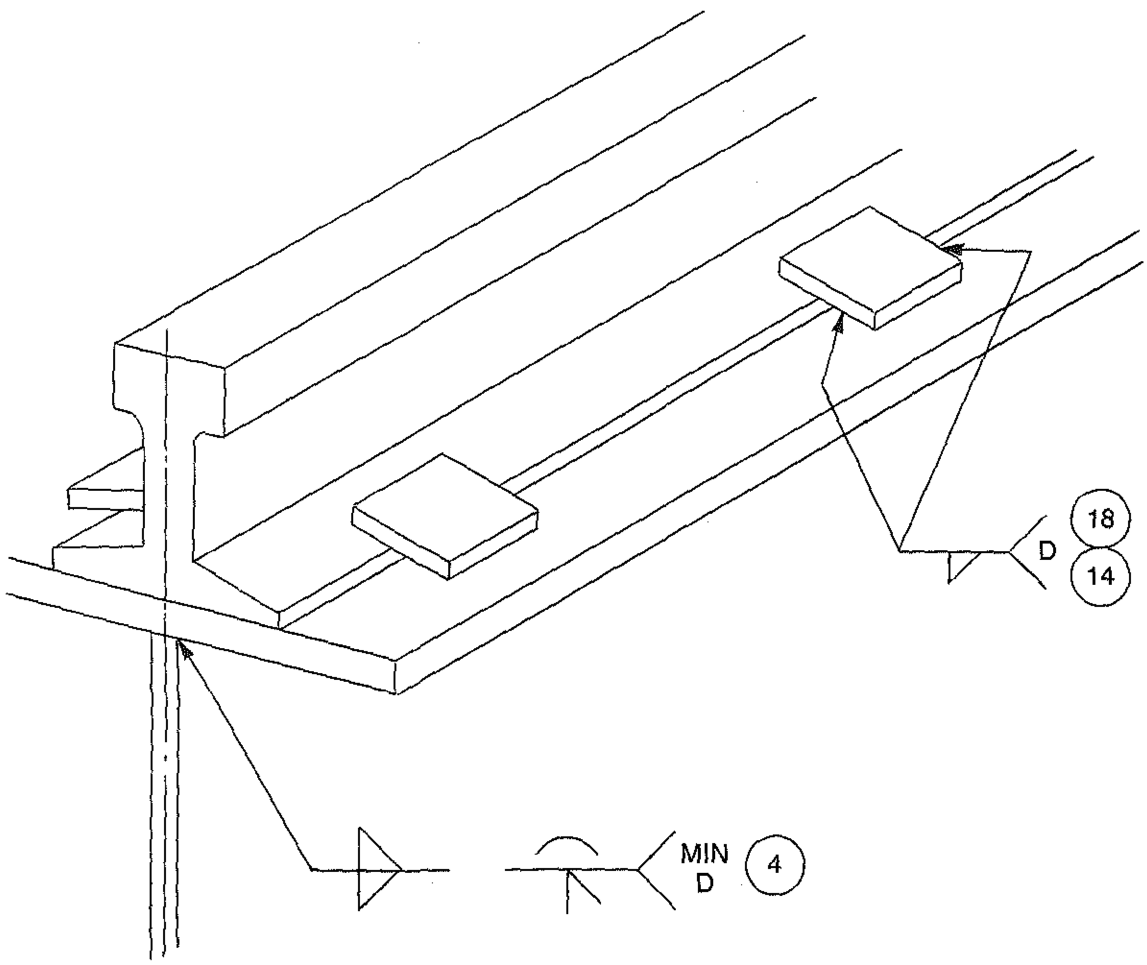
3.4.8 Buckling

3.4.8.1 Local Buckling or Crippling of Flat Plates

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

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

FIGURE NO. 3.4.7-4
FOR TYPICAL TROLLEY RAIL



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

$\sigma_k = K\sigma\,\sigma_e$; $\tau_k = K_\tau\,\sigma_e$

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 (in inches)

b = width of plate (in 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:

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

where:

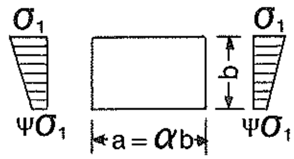
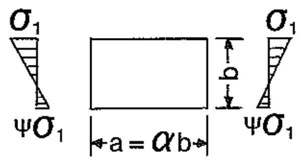
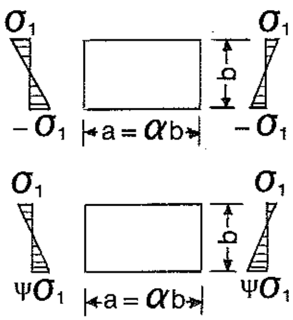
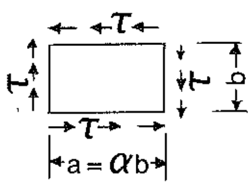
σ = actual compression stress
τ = *actual shear stress*
σ_k = critical compression stress
τ_k = critical shear stress
Ψ = stress ratio (see Table No. 3.4.9.2-1)

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:

$$\sigma_{1kR} = \frac{\sigma_y \sigma_{1k}^2}{0.1836\,\sigma_y^2 + \sigma_{1k}^2}$$

where: σ_y = yield strength
σ_P = *proportional limit* (assumed at $\sigma_y/1.32$)

TABLE NO. 3.4.8.2-1

Case	Loading		Buckling Stress	Range of Application	Buckling Coefficient
1	Compressive stresses, varying as a straight line. $0 \leqslant \Psi \leqslant 1$		$\sigma_k = K_\sigma \sigma_e$	$\alpha \geqslant 1$ $\alpha < 1$	$K_\sigma = \frac{8.4}{\Psi + 1.1}$ $K_\sigma = \left[\alpha + \frac{1}{\alpha}\right]^2 (x) \left[\frac{2.1}{\Psi + 1.1}\right]$
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.		$\tau_k = K_\tau \sigma_e$	$\alpha \geqslant 1$ $\alpha < 1$	$K_\tau = 5.34 + \frac{4.00}{\alpha^2}$ $K_\tau = 4.00 + \frac{5.34}{\alpha^2}$

*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.

3.4.8.3 Design Factors

The buckling safety factor is ϑ_B calculated with the aid of the formula's:

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

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

The design factor DFB requirements of buckling are as follows:

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

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 in inches
b = distance between webplates in inches
h = depth of girder in inches
t = thickness of plate in 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:

$$I_o = 1.2\left[0.4 + 0.6\frac{a}{h} + 0.9\left[\frac{a}{h}\right]^2 + 8\frac{A_s a}{h^2 t}\right] ht^3\text{-in}^4$$

If σ_C is greater than σ_T 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:

$$I_o = 1.2\left[0.3 + 0.4\frac{a}{h} + 1.3\left[\frac{a}{h}\right]^2 + 14\frac{A_s a}{h^2 t}\right] ht^3\text{-in}^4$$

If σ_C is greater than σ_T 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 in inches.

A = area of one longitudinal stiffener in square inches.

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:

3.5.3.2 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:

$$I_o = \left[0.6\frac{a}{b} + 0.2\left[\frac{a}{b}\right]^2 + 3.0\frac{A_s a}{b^2 t}\right] bt^3\text{-in}^4$$

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

$$I_o = \left[2.2 + 10.3\frac{A_s}{bt}\left[1 + \frac{A_s}{bt}\right]\right] bt^3\text{-in}^4$$

3.5.3.3 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:

$$I_o = \left[0.4\frac{a}{b} + 0.8\left[\frac{a}{b}\right]^2 + 8.0\frac{A_s a}{b^2 t}\right]bt^3\text{-in}^4$$

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

$$I_o = \left[9 + 56\frac{A_s}{bt} + 90\left[\frac{A_s}{bt}\right]^2\right]bt^3\text{-in}^4$$

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

$$I_o = \left[0.35\frac{a}{b} + 1.10\left[\frac{a}{b}\right]^2 + 12\frac{A_s a}{b_2 t}\right]bt^3\text{-in}^4$$

where:

a = longitudinal distance between diaphragms or transverse stiffeners - inches

A_s = area of the stiffener - square inches

t = thickness of the stiffened plate - inches

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:

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

where: a = longitudinal distance between diaphragms or transverse stiffeners - inches

t = thickness of web in inches

v = shear stress in web plates (k.s.i.)

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:

$$I = \frac{1.2\,h^3\,t_0^3}{a_0^2}\ \text{in}^4$$

where: a_0 = required distance between stiffeners - inches

t_0 = minimum required web thickness - inches

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 suitably reinforced with full depth diaphragms or stiffeners at all major load points.

3.5.4.5 All diaphragms shall bear against the top cover plate and shall be welded to the web plates. The thickness of the diaphragm plate shall be sufficient to resist the trolley wheel load in bearing at the allowable bearing stress on the assumption that the wheel load is distributed over a distance equal to the width of the rail base plus twice the distance from the rail base to the top of the diaphragm plate.

3.5.4.6 Short diaphragms shall be placed between full depth diaphragms so that the maximum distance between adjacent diaphragms will limit the maximum bending stress in the trolley rail without VIF forces to 18 ksi for load combination Case 1, Section 3.3.2.4.1 based on:

$$\frac{\text{(trolley wheel load) (distance between diaphragms)}}{6 \text{ (section modulus of rail)}} \leqslant 18 \text{ ksi}$$

maximum = 19.8 ksi for Case 2 and 22.5 ksi for Case 3

3.5.5 Deflection and Camber

3.5.5.1 The maximum vertical deflection of the girder produced by the weight of the trolley and the rated load shall not exceed 0.001125 inch per inch of span. VIF forces shall not be considered in determining deflection.

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

3.5.6 Welded Torsion Box Girders:

3.5.6.1 Torsion girders, with the trolley rail over one web plate, are to be designed with the trolley wheel load assumed to be distributed over a distance of the web plate as indicated in Section 3.3.2.3.

3.5.6.2 For box girders having compression flange areas no more than 50 percent greater than that of the tension flange, and with no more than 50 percent difference between the areas of the two webs, the shear center may be assumed to be at the centroidal axis of the cross section.

3.5.7 Single Web Girders

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

The maximum vertical deflection of the girder produced by the weight of the trolley and the rated load shall not exceed .001125 inch per inch of span. VIF forces shall not be considered in determining deflection.

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

Tension (net section) $= 0.6\,\sigma_{yp}$

$$\text{Compression} = \frac{12{,}000}{\frac{Ld}{A_f}} \text{ with maximum of } 0.6\sigma_{yp}$$

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

where: L = span (unbraced length of top flange) in inches

A_f = area of compression flange in square inches

d = depth of beam in inches

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

3.5.8 Box Section Girders Built of Two Beams

Box section girders 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 1/7 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 a drop of the crane not more than one inch in case of axle failure. Guards shall be provided in front of each outside wheel and shall project below the top of the runway rail. Load combinations and basic allowable stresses are to be in accordance with Sections 3.3.2.4 and 3.4.

3.7 FOOTWALKS AND HANDRAILS

A footwalk with a substantial handrail should be provided where required and specified. The handrail shall be at least 42 inches high and provided with an intermediate railing. The footwalk shall have a slip-resistant walking surface. The footwalk shall be protected on all exposed edges by a suitable toe guard. *All footwalks shall be designed for a live load of 50 pounds per square foot. For* allowable stresses, use stress level 2, Section 3.4.2.

3.8 OPERATOR'S CAB

3.8.1 *The standard location of the operator's cab is at one end of the crane bridge on the driving girder* side unless otherwise specified. It shall be so located as not to interfere with the hook approach. The operator's cab shall be open type for indoor service unless otherwise specified. 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.*

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

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

3.8.4 The controllers or their operating handles are located as shown in Section 5.7 for the cab location, unless otherwise specified.

3.8.5 Means of access and egress from cab should comply with ANSI B30.2.

3.9 TROLLEY FRAMES

3.9.1 The trolley frame shall be constructed of structural steel and shall be designed to transmit the load to the bridge rails without deflection which will impair functional operation of machinery.

3.9.2 Provision should be made to prevent a drop of more than one inch in case of axle failure.

3.9.3 Load combinations and allowable stresses are to be as specified in Sections 3.3.2.4 and 3.4.

3.10 BRIDGE RAILS

3.10.1 All bridge rails shall be of first quality and conform to all requirements set forth in the specifications of the ASCE, ARA, AREA or any other commercial rolled sections with equivalent specifications.

3.10.2 Bridge rails shall be joined by standard joint bars or welded. The ends of non-welded sections shall be square and sections joined without opening between ends. Provision shall be made to prevent creeping of the bridge rails.

3.10.3 Bridge rails shall be securely fastened in place to maintain center distance of rails.

3.10.4 Bridge and trolley rails should be in accordance with Table 4.13.3-4 and consistent with the wheel diameter and the maximum wheel load.

3.11 END TIES

End ties are to be provided between girders when deemed necessary for stability of the girders, to assist in squaring the crane, to participate with the girders in continuous frame action to resist horizontal loads, and to accommodate unbalanced torsional loads on the girders. When equalizer bridge trucks are incorporated in the crane design, the end ties shall be of rigid construction and of adequate strength to resist all of the above loads. Flexibility of the end tie is necessary when equalizing provisions are not employed. Due consideration should be given to the various types of loading conditions and the resulting stresses, which shall not exceed the values as stated in Section 3.4.

3.12 BRIDGE TRUCKS FOR 8, 12 AND 16 WHEEL CRANES

3.12.1 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.

3.12.2 For typical arrangement of 8, 12 and 16 wheel cranes, see Figure 3.12.2-1.

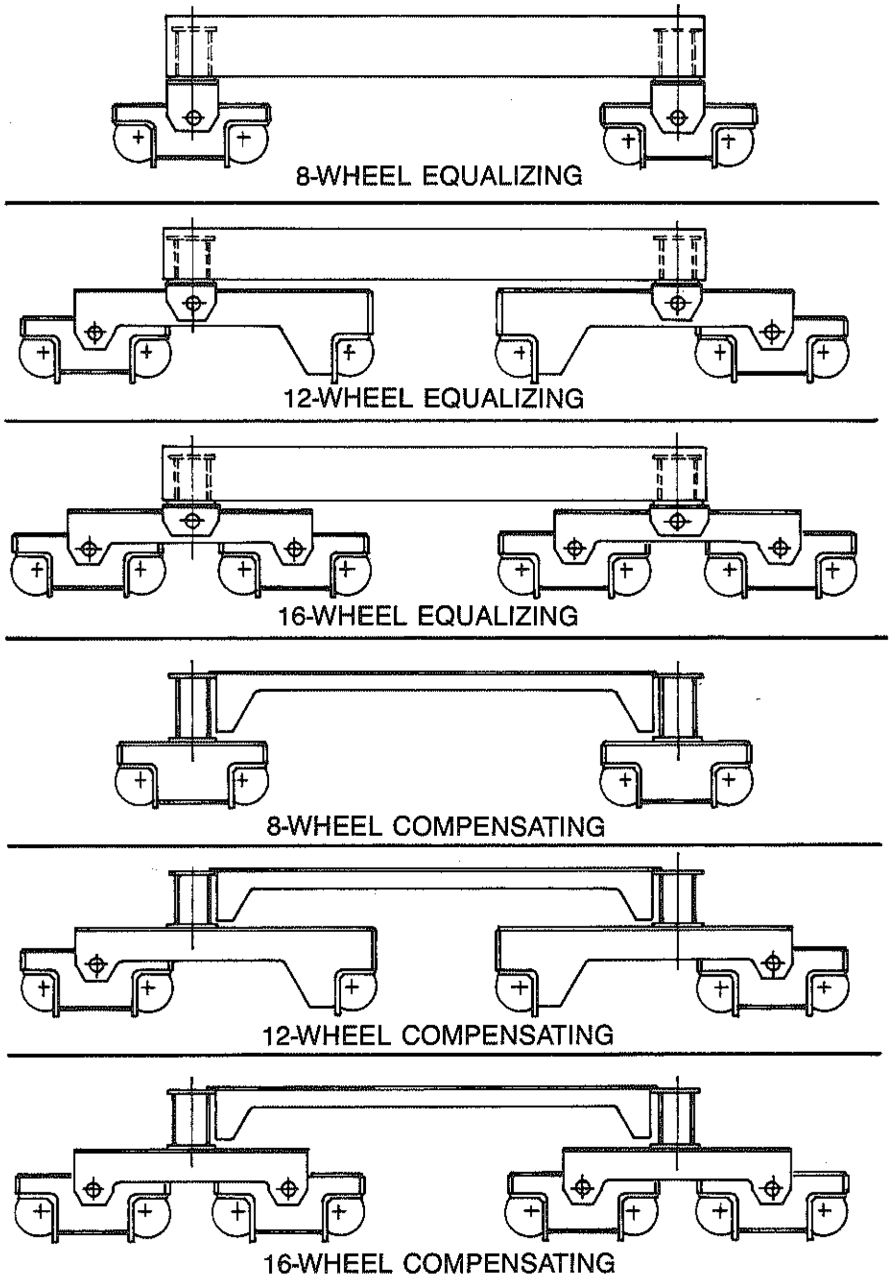


FIGURE 3.12.2-1

3.13 STRUCTURAL BOLTING

3.13.1 Joints designed as high strength bolted connections are to conform to the requirements of the "Specification for Structural Joints Using ASTM A325 or A490 Bolts," as published by AISC, for load combination, Case 1, Section 3.3.2.4.1. Zinc causes stress corrosion in A490 and should not be used.

3.13.2 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 3.3.2.4.1.

3.13.3 Allowable bolt stresses for load combination Cases 2 and 3, Sections 3.3.2.4.2 and 3, are to be proportioned in accordance with Sections 3.4.1;2 and 3.

3.14 GANTRY CRANES

Design of leg, end tie, strut, and sill members shall conform to applicable sections of this specification.

70-4 MECHANICAL DESIGN

4.1 MEAN EFFECTIVE LOAD

Note: In order to facilitate a measure of durability, load and service factors shall be used to determine the mean effective load in a service classification for mechanical components.

4.1.1 The mechanical mean effective load factor Kw shall be established by the use of the following basic formula.

$$Kw = \frac{2(\text{maximum load}) + (\text{minimum load})}{3(\text{maximum load})}$$

The maximum load used in the above formula shall be established by using the rated load so positioned as to result in the maximum reaction on the component under consideration. Impact shall not be included. The minimum load to be used shall be established by the dead load of the bridge and or trolley only.

4.1.2 Load factors Kw convert maximum loads into mean effective loads as follows, and are to be used for gear durability horsepower and bearing life calculations.

$$\text{Mean effective load} = \text{Maximum load} \times Kw$$

4.1.2.1 The load factor Kwh for the hoist machinery is established by the following formula:

$$Kwh = \frac{2(\text{rated load}) + 3(\text{lower block weight})}{3(\text{rated load} + \text{lower block weight})}$$

Lower blocks weighing less than 2 percent of rated capacity may be ignored resulting in Kwh = .667.

4.1.2.2 The load factor Kwt for the trolley drive machinery is established by the following formula:

$$Kwt = \frac{2(\text{rated load}) + 3(\text{trolley weight})}{3(\text{rated load} + \text{trolley weight})}$$

4.1.2.3 The load factor Kwb for the bridge drive machinery is established by the following formula:

$$Kwb = \frac{2(\text{rated load}) + 3(\text{trolley weight} + \text{bridge weight})}{3(\text{rated load} + \text{trolley weight} + \text{bridge weight})}$$

4.1.2.4 For Kw factors of trolley and bridge wheel assemblies, see Section 4.13.3. Kbw and Ktw are to be used for axle bearing selection.

4.1.3 The machine service factor Cd listed in Table 4.1.3-1 depends on the class of crane service and accounts for expected differences of load spectrum density and severity of service and is used to determine gear durability horsepower.

4.1.4 Stress concentration factors can be obtained from data in stress concentration factors by R. E. Peterson (see Section 1.1.6).

TABLE 4.1.3-1

Machinery Service Factor Cd

Class of Service	A	B	C	D	E	F
Cd	.64	.72	.8	.9	1.0	1.16

4.2 LOAD BLOCKS

4.2.1 The load block frame should be of steel construction. Care shall be taken to minimize changes in geometry that may cause stress concentrations. The frame shall be designed for rated load. The rated load stress shall not exceed 20 percent of the average ultimate strength of the material used. Where stress concentrations exist, the stress as amplified by the appropriate amplification factor with due consideration for impact and service shall not exceed the endurance strength of the material used. Other materials agreed upon by the manufacturer and recognized as suitable for the application may be used, provided the parts are proportionate to give appropriate design factors.

4.2.2 The hook shall be of rolled steel, forged steel or a material agreed upon by the manufacturer and recognized as suitable for the application. The hook shall be designed based on the rated load.

4.2.2.1 The hook rated load stress shall be calculated considering the rated load on the hook using:

A. Straight beam theory with the calculated combined stresses not to exceed 20 percent of the material's average ultimate strength.

—OR—

B. Modified curved beam theory with the calculated combined stresses not to exceed 33 percent of the material's average ultimate strength.

—OR—

C. Plastic theory or testing with the combined stresses not to exceed 20 percent of the stress produced by the straightening load as obtained by test or calculation by this theory.

4.2.2.2 The hook shall rotate freely and be supported on a thrust bearing. The hook shank stress shall be calculated considering the rated load and shall not exceed 20 percent of the material's average ultimate strength. At points of geometric discontinuities, the calculated stress as amplified by the appropriate stress amplification factor with due consideration for impact and service shall not exceed the endurance strength.

4.2.2.3 Other lifting attaching devices, such as eye bolts and twist locks, shall be designed to applicable portion of Sections 4.2.2.1 and 4.2.2.2.

4.2.2.4 Load block sheave pins and trunnions shall be designed per the applicable Section 4.11.4 of this specification.

4.3 OVERLOAD LIMIT DEVICE

4.3.1 An overload limiting device is normally only provided when specified. Such device is an emergency device intended to permit the hoist to lift a freely suspended load within its rated capacity, but prevents lifting of an overload that would cause permanent damage to a properly maintained hoist, trolley or crane.

4.3.1.1 Variables experienced within the hoist system, such as, but not limited to, acceleration of the loads, dynamics of the system, type and length of wire rope, and operator experience, render it impossible to adjust an overload device that would prevent the lifting of any overload or load in excess of rated load.

4.3.1.2 The adjustment of an overload device, when furnished, will allow the lifting of an overload of such magnitude that will not cause permanent damage to the hoist, trolley, or crane, and shall prevent the lifting of an overload of such magnitude that could cause permanent damage to a properly maintained hoist, trolley, or crane.

4.3.1.3 The overload device is actuated only by loads incurred when lifting a freely suspended load on the hook. Therefore, an overload device cannot be relied upon to render the hoisting mechanism inoperative if other sources, such as but not limited to, snagging of the load, two blocking of the load block, or snatching a load, induce loads into the hoisting system.

4.3.1.4 The overload limit device is connected into the hoisting control circuit and, therefore, will not prevent damage to the hoist, trolley, or crane, if excessive overloads are induced into the hoisting system when the hoisting mechanism is in a nonoperating or static mode.

4.4 HOISTING ROPES

4.4.1 The hoisting rope shall be of proper design and construction for crane service. The rated capacity load plus the load block weight divided by the number of parts of rope shall not exceed 20 percent of the published breaking strength of the rope except ropes used for holding or lifting molten metal which shall not exceed 12.5 percent of the published breaking strength of the rope.

4.4.2 The wire rope construction shall be as specified by the crane manufacturer. When extra strength steel or wire center rope is used, the crane manufacturer's specifications shall so state.

Wherever exposed to temperatures at which fibre cores would be damaged, ropes having an independent wire-rope, wire strand core, or other temperature-resistant core shall be used.

4.4.3 Rope Fleet Angle

4.4.3.1 Rope fleet angle for drums. The fleet angle of the rope should be limited to 1 in 14 slope (4 degrees) as shown in Figure 4.4.3.1-1.

4.4.3.2 Rope fleet angle for sheaves. The fleet angle of the rope should be limited to 1 in 12 slope (4 degrees-45 minutes) as shown in Figure 4.4.3.2-1.

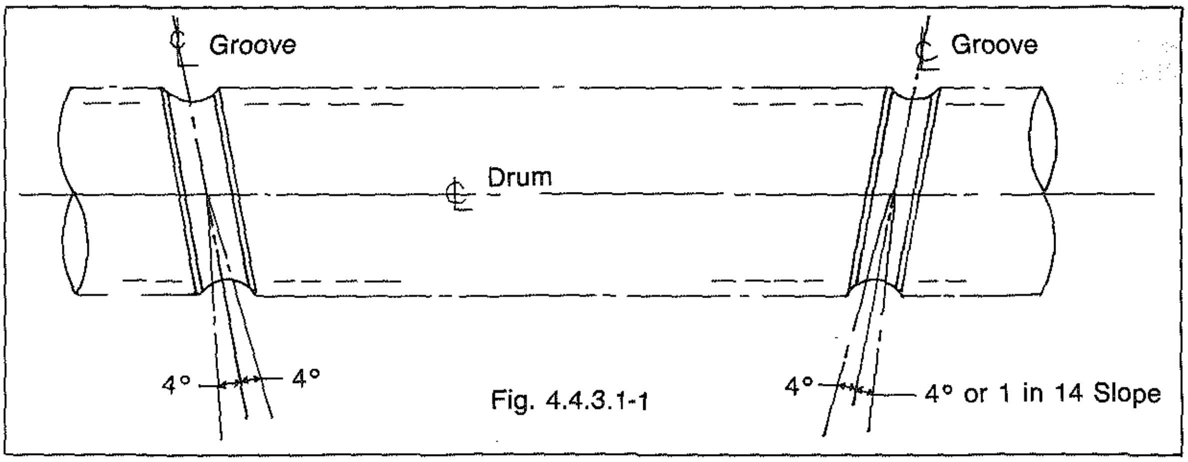


Fig. 4.4.3.1-1

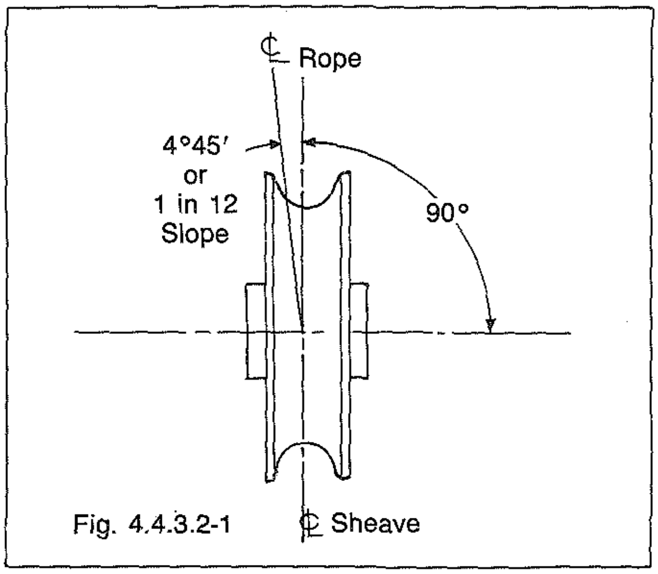


Fig. 4.4.3.2-1

4.6.4 Table 4.6.4-1 is a guide for minimum pitch diameter of drums. Smaller drums may cause an increase in rope maintenance.

TABLE 4.6.4-1

GUIDE FOR MINIMUM PITCH DIAMETER OF DRUMS

CMAA Class	6 × 37 Class Rope	6 × 19 Class Rope
A & B	16 × d	20 × d
C	18 × d	24 × d
D	20 × d	24 × d
E	24 × d	30 × d
F	30 × d	30 × d

d = rope diameter

4.6.5 When special clearance, lift or low headroom is required, it may be necessary to deviate from these limitations.

4.7 GEARING

4.7.1 The types of gearing shall be specified by the crane manufacturer.

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

For the purpose of this specification, the strength and durability shall be based on the torque required to lift the rated load for hoist gearing and the motor name plate rating for travel gearing. 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 total motor torque than gearing for hoist drives.

4.7.3 The horsepower rating for all spur, helical and herringbone gearing shall be based upon American Gear Manufacturers Association (AGMA) Standards: 220.02, 'Rating the Strength of Spur Gear Teeth', 210.02, 'Surface Durability (Pitting) of Spur Gear Teeth', 221.02, 'Rating the Strength of Helical and Herringbone Gear Teeth', and 211.02, 'Surface Durability (Pitting) of Helical and Herringbone Gear Teeth'. For the purpose of this specification, the power formula may be written:

NOTE: Published year dates to be referenced in another part of the specification.

Allowable strength horsepower—

$$Pat = \frac{Np\ d\ Kv}{126000} \cdot \frac{F\ Sat\ J}{Km\ Pd\ Sf}$$

Allowable durability horsepower—

$$Pac = \frac{Np\ F\ I\ Cv}{126000\ Cm\ Sfd} \cdot \left[\frac{Sac\ d\ Ch}{Cp}\right]^2$$

where: Pat — allowable strength horsepower
Pac — allowable durability horsepower
Np — pinion speed—revolution per minute
d — pitch diameter of pinion—inches
Kv — dynamic factor (strength)
Cv — dynamic factor (durability)
F — net face width of the narrowest of the mating gears
Km — load distribution factor (strength)
Cm — load distribution factor (durability)
Cp — elastic coefficient
Ch — hardness factor (durability)
J — geometry factor (strength)
I — *geometry factor (durability)*
Pd — diametral pitch
Sat — allowable bending stress for material—pounds per square inch (strength)
Sac — allowable contact stress number (durability)
Sf — crane service factor (strength)
Sfd — *crane service factor (durability)*

The values for Kv, Cv, Ch, Km, Cm, Cp, J, I, Sac and Sat can be determined from the tables and curves in the appropriate AGMA specification previously mentioned, Sf in Section 4.7.4, the remaining values will be physical characteristics pertaining to the gears for their operation characteristics.

Crane service factor Sfd shall be determined from the formula Sfd = Cd × Kw. For values of specific Kw refer to Section 4.1 and for the values of Cd refer to Section 4.1.3 for the crane class. Note: Kw = Load Factor, Cd = Machinery Service Factor.

4.7.4 The crane service factors for strength horsepower are as shown in Table 4.7.4-1.

TABLE 4.7.4-1

Crane Class	Sf
A	.75
B	.85
C	.90
D	.95
E	1.0
F	1.05

4.7.5 When worm gearing is called for, it shall be rated by the gear manufacturer with appropriate service factors. Due consideration should be given for lock up when selecting gear ratios for travel drives.

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

4.7.7 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.

4.8 BEARINGS

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

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

AFBMA L-10 BEARING LIFE

Class A	1250 Hours
Class B	2500 Hours
Class C	5000 Hours
Class D	10000 Hours
Class E	20000 Hours
Class F	40000 Hours

Use Kw load factor for all applications as determined in Section 4.1 of this specification.

*Due consideration to 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.'

4.8.3 Sleeve bearings shall have a maximum allowable unit bearing pressure as recommended by the bearing manufacturer.

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

4.9 BRAKES

4.9.1 Hoist Holding Brakes

4.9.1.1 Each independent hoisting unit of a crane shall be equipped with at least one holding brake. This brake shall be applied directly to the motor shaft or some other shaft in the hoist gear train.

4.9.1.2 Hoist holding brakes shall have minimum torque ratings, stated as a percentage of the rated load hoisting torque, at the point where the holding brake is applied as follows:

4.9.1.2.1 125 percent when used with a control braking means other than mechanical.

4.9.1.2.2 100 percent when used with mechanical control braking means.

4.9.1.2.3 100 percent for each holding brake if two holding brakes are provided.

4.9.1.3 Hoist holding brakes shall have thermal capacity for the frequency of operation required by the service.

4.9.1.4 Hoist holding brakes shall be provided with means to compensate for lining wear.

4.9.1.5 Each independent hoisting unit of a crane that handles molten materials shall have one of the following arrangements:

4.9.1.5.1 Two holding brakes (one of which is mounted on a gear reducer shaft) plus control braking means shall be provided. Each brake shall have a minimum torque rating equal to rated load hoisting torque at the point where the brake is applied.

4.9.1.5.2 If the hoist unit has a mechanical load brake or a controlled braking means that provides emergency braking in the lowering direction upon loss of power, only one holding brake is required. The holding brake shall have a minimum torque rating equal to 150 percent of the rated load hoisting torque at the point where the brake is applied.

4.9.2 Hoist Control Braking Means

4.9.2.1 Each independent hoisting unit of a crane, except worm-geared hoists, the angle of whose worm is such as to prevent the load from accelerating in the lowering direction, shall be equipped with control braking means to control lowering speeds.

4.9.2.2 Control braking means shall be mechanical, hydraulic, pneumatic or electric power (such as eddy current, dynamic, regenerative or counter torque). All methods must be capable of maintaining controlled lowering speeds. The inherent regenerative controlled braking means of a squirrel cage motor may be used if the holding brake is designed to meet the additional requirement of retarding a decending load upon power removal.

4.9.2.3 Hoist control braking means shall have thermal capacity for the frequency of operation required by the service.

4.9.3 Trolley Brakes

4.9.3.1 On cab operated (non-skeleton) cranes with cab on trolley, a trolley brake shall be provided having torque capability to stop the trolley motion within distance in feet equal to 10 percent of rated load speed in feet per minute when traveling at rated speed with rated load.

4.9.3.2 On cab-operated (non-skeleton) cranes with cab on bridge, a trolley brake or non-coasting mechanical drive may be provided when specified. When provided, the brake or non-coasting mechanical drive shall meet the stop travel distance requirements of Section 4.9.3.1

4.9.3.3 On floor, remote or pulpit-operated cranes, including skeleton cab-operated cranes, a trolley brake or non-coasting mechanical drive may be provided when specified. When provided, the brake or non-coasting mechanical drive shall meet the stop travel distance requirements of Section 4.9.3.1.

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

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

4.9.3.6 A drag brake may be applied to hold the trolley in a desired position on the bridge and to eliminate creep with the power off.

4.9.3.7 The minimum requirements for trolley brakes and braking means per ANSI B30.2.0 is shown in Figure 4.9.3.7-1.

FIGURE 4.9.3.7-1
Trolley Brakes

CAB OPERATED				FLOOR	
Attached to Trolley		Attached to Bridge		Remote or Pulpit Operated	
Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
Service Emergency ▨	Service Emergency Parking ▨	Drag ☐	Drag ☐	Emergency or Drag or Non-Coasting Mechanical Drive ☐	Emergency or Drag or Non-Coasting Mechanical Drive ☐

▨ A trolley brake is required.
☐ A trolley brake is not required.

4.9.4 Bridge Brakes.

4.9.4.1 On cab-operated (non-skeleton) cranes, a bridge brake shall be required having torque capability to stop the bridge motion within a distance in feet equal to 10 percent of rated load speed in feet per minute when traveling at rated speed with rated load.

4.9.4.2 On floor, remote or pulpit-operated cranes including skeleton (dummy) cab-operated cranes, a bridge brake or non-coasting mechanical drive shall be required having torque capability to stop the bridge motion within a distance in feet equal to 10 percent of rated load speed in feet per minute when traveling at rated speed with rated load.

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

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

4.9.4.5 On cranes designed with high speed and high acceleration rates, consideration should be given to provide braking means to achieve proportionally high deceleration rates.

4.9.5 General brake comments for normal cab-operated cranes.

4.9.5.1 Foot operated brakes shall require an applied force of not more than 70 pounds to develop rated brake torque.

4.9.5.2 Brake pedals, latches, and levers should be designed to allow release without the exertion of greater force than was used in applying the brake.

4.9.5.3 Brakes should be applied by mechanical, electrical, pneumatic, hydraulic or gravity means.

4.9.5.4 All foot-brake pedals shall be constructed so that the operator's foot will not readily slip off the pedal.

4.9.5.5 Foot-operated brakes shall be equipped with a means for positive release when force is released from the pedal.

4.9.5.6 The foot-brake pedals should be so located that they are convenient to the operator at the controls.

4.9.5.7 If parking brakes are provided on the bridge or trolley, they shall not prohibit the use of a drift point in the control circuit.

4.9.5.8 The minimum requirements for bridge brakes and braking means per ANSI B30.2.0 is shown in Figure 4.9.5.8-1.

Figure 4.9.5.8-1
Bridge Brakes

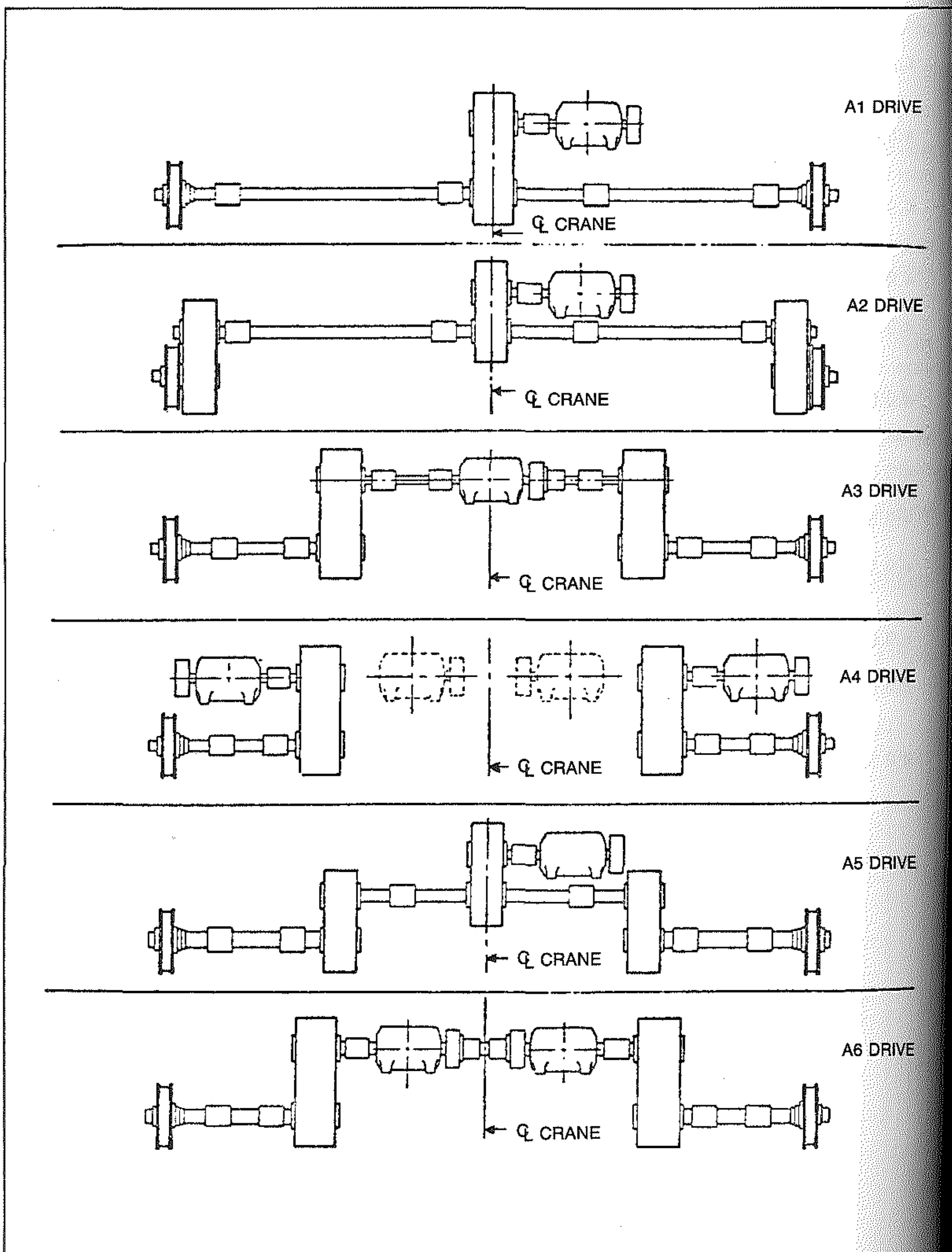
CAB OPERATED				**FLOOR**	
Attached to Trolley		Attached to Bridge		Remote or Pulpit Operated	
Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
Service Emergency ▨	Service Emergency ▨	Service ▨	Service ▨	Emergency or Non-Coasting Mechanical Drive ▨	Emergency or Non-Coasting Mechanical Drive ▨

▨ A bridge brake is required.
☐ A bridge brake is not required.

4.10 BRIDGE DRIVES

4.10.1 Bridge drives shall consist of one of the following arrangements, as specified on information sheets and as illustrated in Figure 4.10.1-1. These arrangements cover most four or eight wheel crane drives. For the number of driven wheels for a specific acceleration rate—refer to the electrical Section 5.2.9.1.2.1 A & B of this specification.

FIGURE 4.10-1-1
ARRANGEMENT OF CRANE BRIDGE DRIVES



4.10.1.1 A-1 Drive: The motor is located near the center of the bridge and connected to a self-contained gear reduction unit located near the center of the bridge. Output of the gear reduction shall be connected directly to the truck wheel axles by means of suitable shafts and couplings.

4.10.1.2 A-2 Drive: The motor is connected to a self-contained gear reduction unit located near the center of the bridge. The truck wheels shall be driven through gears pressed and keyed on their axles or by gears fastened to, or integral with, the truck wheels and with pinions mounted on the end sections of the cross-shaft. The end sections of the cross-shaft shall be connected by suitable couplings.

4.10.1.3 A-3 Drive: The motor is located at the center of the bridge and is connected to the cross-shaft and the gear reduction units with suitable couplings. Self-contained gear reduction units located near each end of the bridge shall be either directly connected to the wheel axle extension or connected to wheel axles by means of shafts with suitable couplings.

4.10.1.4 A-4 Drive: The motors are located near each end of the bridge without torque shafts. The motors shall be connected to self-contained gear reduction units. The gear reduction units shall be applied to the truck wheels by means of either suitable shafts and couplings or directly mounted to the wheel axle shaft extension. Another variation of this drive would separate the high speed and final reductions by locating the motors near each end of the bridge without torque shafts. The motors will be connected to self-contained high speed gear boxes which will drive the truck wheels through gears pressed and keyed on their axles or by gears fastened to the truck wheels, and with pinions mounted on the end section on the shaft from the high speed gear box and the final reduction shall be connected by means of suitable shafts and couplings.

4.10.1.5 A-5 Drive: The motor is located near the center of the bridge and is connected to a self-contained gear reduction unit located near the center of the bridge. This reduction unit shall be connected by sections of cross-shaft having suitable couplings to self-contained gear reduction units located near each end of the crane, and these in turn connected to truck wheel axles by means of shafts with suitable couplings.

4.10.1.6 A-6 Drive: The motors are located near each end of the bridge and connected with a torque shaft. On the drive end, the motors shall be connected to self-contained gear reduction units by suitable couplings. The output of the gear reduction units shall be connected directly to the truck wheel axle by means of suitable shafts and couplings.

4.11 SHAFTING

4.11.1 General Nomenclature and Values for Section 4.11

TABLE 4.11.1-1

SURFACE CONDITION FACTOR
Ksc

Ksc	SURFACE CONDITION
1.4	For Polished-Heat treated and inspected shafting
1.0	For Machined-Heat treated and inspected shafting
.75	For Machined-General usage shafting

TABLE 4.11.1-2

CRANE CLASS	CRANE CLASS FACTOR Kc
A	1.0
B	1.015
C	1.03
D	1.06
E	1.125
F	1.25

Se = endurance strength of shaft material = .36 Su′ Ksc
Su = average tensile strength of shaft material
Su′ = minimum tensile strength of shaft material
Syp = minimum yield strength of shaft material
σav = that part of the bending stress not due to fluctuating loads
τav = that part of the shear stress not due to fluctuating loads
σr = that part of the bending stress due to fluctuating loads
τr = that part of the shear stress due to fluctuating loads
Kt = stress amplification factor for tension or bending
Ks = stress amplification factor for shear
Kc = crane class factor
Ksc = surface condition factor

4.11.2 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:

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

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 preceeding formula whichever is less in order to avoid objectionable vibration at critical shaft speeds:

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

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

4.11.3 The torsional deflection of the bridge cross-shaft shall not exceed the values shown on Table 4.11.3-1. The types of drive referred to on the table are as defined in Section 4.9 and the percent motor torque is the portion of the full load torque of the bridge drive motor(s) at its normal time rating for the service involved, increased by any gear reduction between the motor and the shaft. The allowable angular deflection is expressed in degrees per foot. In addition the total angular deflection produced by the motor torque in Table 4.11.3-1 should result in a bridge drive wheel movement no greater than percent of the wheel circumference or 0.5 inch on the circumference, whichever is less.

TABLE 4.11.3-1

Maximum Allowable Angular Deflection Degrees Per Foot

Type of Drive	Percent Motor Torque	Cab Controlled Cranes	Floor & Remote Controlled Cranes
A1	67	.080	0.10
A2	50	.080	0.10
A3	67	.080	0.10
A4	100	.070	0.10
A5	50	.080	0.10
A6	100	.070	0.10

4.11.4 Stress Calculations

All shafting shall be designed to meet the stresses encountered in actual operation. For the purposes of this specification, the strength shall be based on the torque required to lift the rated load for hoist machinery and the motor nameplate rating for drive machinery. Due consideration shall be given to the maximum brake torque which may be applied to the 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.

4.11.4.1 Static Stress Check for Operating Conditions

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

$$\sigma = P/A$$

P = total axial load
A = cross sectional area of shaft

This axial stress shall not exceed Su/5.

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

$$\sigma = Mr/I$$

M = bending moment at point of examination
r = outside radius of shaft at point of examination
I = bending moment of inertia at point of examination

This bending stress shall not exceed Su/5.

C. For shafting loaded in torque, the shear stress shall be calculated as follows -

$$\tau = Tr/J$$

T = torque at point of examination
r = outside radius of shaft at point of examination
J = polar moment of inertia of shaft at point of examination

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

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

For Solid Shaft -

$$\tau = 1.33\ V/A$$

V = shear load at point of examination

For Hollow Shafts-

$$\tau = 2\ V/A$$

A = cross sectional area at point of examination

These shear stresses shall not exceed $Su/(5\sqrt{3})$.

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

axial and bending stresses

$$\sigma = \sigma_1 + \sigma_2 + \sigma_3 + \ldots + \sigma_n$$

and shall not exceed Su/5

shear stresses

$$\tau = \tau_1 + \tau_2 + \ldots + \tau_n$$

and shall not exceed Su/(5 $\sqrt{3}$).

axial and bending with shear:

$$\sigma_t = \sqrt{\sigma^2 + 3\tau^2}$$

This stress shall not exceed Su/5.

Note that bending and torsional stresses are maximum on the outer fibers of the shaft and must be combined. The transverse shear stresses are maximum at the center of the shaft and do not combine with bending or torsional stresses.

4.11.4.2 Fatigue Stress Check for Fluctuating, Operating Stresses

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 in addition to Section 4.11.4.1 and need only be performed at points of geometric discontinuity where stress concentrations exist, such as fillets, holes, keys, press fits, etc. pure stresses, ie, (not combined) are to be calculated as in Section 4.11.4.1 except multiplied by the appropriate stress amplification factor. The allowable stresses are as follows.

A. Tensile and bending stress, ie, $\sigma \cdot K_t \leqslant \frac{S_e}{K_c}$

B. Shear and combined shear, ie, $\tau \cdot K_s \leqslant \frac{S_e}{K_c\sqrt{3}}$

C. For combined stresses where all of the shear and bending is fluctuating -

$$\sigma_t = \sqrt{(K_t\sigma)^2 + 3(K_s\tau)^2} \leqslant \frac{S_e}{K_c}$$

D. For combined shear and bending where only part of the stresses are fluctuating -

$$\sigma_t = \sqrt{(\sigma_{av} + K_t S_{yp}\sigma_r/Se)^2 + 3(\tau_{av} + K_s S_{yp}\tau_r/S_e)^2} \leqslant \frac{S_{yp}}{K_c}$$

4.11.5 Shafting in bearing must be checked for operating conditions. The bearing stress is calculated by dividing the radial load by the projected area, ie, P/(d . 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.

4.12 COUPLINGS

4.12.1 Cross-shaft couplings, other than flexible type, shall be steel or minimum ASTM Grade A48, latest edition, Class 40 cast iron or equal material as specified by the crane manufacturer. The type of coupling (other than flexible) may be compression, sleeve or flange type. Flexible couplings shall be the crane manufacturer's standard type.

4.12.2 Motor couplings shall be as specified by the crane manufacturer.

4.13 WHEELS

4.13.1 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 toward the center of the span. Trolley wheels should have straight treads. Drive wheels shall be matched pairs within .001 inches per inch of diameter or a total of .010 inches on the diameter, whichever is smaller. When flangeless wheel and side roller assemblies are provided, they shall be of a type and design recommended by the crane manufacturer.

4.13.2 Wheels shall be rolled or forged from open hearth, basic oxygen or electric furnace steel, or cast of an acceptable carbon or alloy steel unless otherwise specified. Wheels shall be heat treated only if specified. Other suitable materials may be used. Due consideration shall be given to the brittleness and impact strength of the material used.

4.13.3 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 impact. 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: $K = BHN \times 5$ (for wheels with $BHN \leqslant 260$)

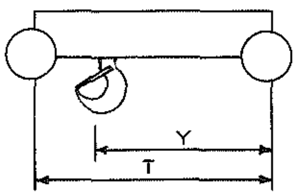
$K = 1300\,(BHN/260)^{.33}$ (for wheels with $BHN \geqslant 260$)

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 4.13.3-4. The values in the table are established by the product of $D \times W \times K$. In addition, the load factor, Kw, the speed factor Cs, and the crane service class shall be considered.

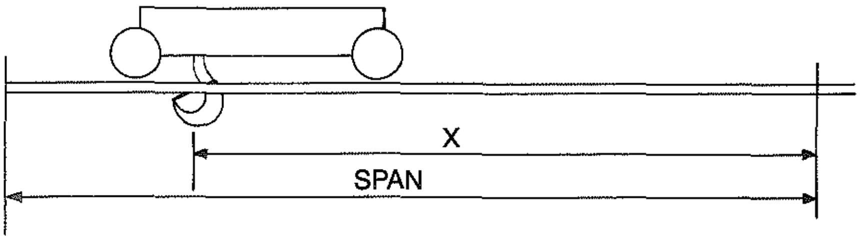
4.13.3.1 The load factor Ktw for the trolley wheels is established by the following formula:

$$Ktw = \frac{(2Y \text{ rated load}/T) + 1.5\ TW}{(3Y \text{ rated load}/T) + 1.5\ TW}$$

Where TW = trolley weight
Where Ktw = trolley load factor



The load factor Kbw for the bridge wheels is established by the following formula or Table 4.13.3-1 may be used for standard hook cranes in lieu of calculating the exact value for a particular application. Other cranes may require special considerations. The factors shown at 100-ton capacity may be used for capacities above 100-tons.



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

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

TABLE 4.13.3-1

TYPICAL BRIDGE LOAD FACTORS Kbw

BRIDGE SPAN FT.	CAPACITY IN TONS						
	3	5	7½	10	15	20	25
20	.812	.782	.762	.747	.732	.722	.716
30	.817	.785	.767	.750	.736	.725	.718
40	.827	.794	.777	.760	.744	.732	.723
50	.842	.809	.791	.771	.758	.740	.738
60	.861	.830	.807	.790	.773	.754	.747
70	.877	.844	.825	.807	.789	.768	.760
80	.888	.857	.835	.818	.802	.779	.770
90	.898	.869	.850	.832	.815	.792	.782
100	.912	.883	.867	.848	.826	.806	.796
110	.926	.890	.882	.863	.844	.823	.812
120	.934	.909	.894	.879	.860	.834	.827

TABLE 4.13.3-1 - Continued

TYPICAL BRIDGE LOAD FACTORS Kbw

BRIDGE SPAN FT	CAPACITY IN TONS						
	30	35	40	50	60	75	100
20	.716	.714	.713	.713	.709	.709	.708
30	.718	.715	.713	.711	.708	.708	.706
40	.723	.722	.717	.714	.711	.711	.708
50	.731	.728	.723	.720	.716	.715	.711
60	.741	.736	.729	.726	.722	.721	.717
70	.752	.746	.738	.734	.729	.727	.723
80	.761	.754	.746	.742	.738	.735	.730
90	.774	.767	.758	.754	.747	.744	.737
100	.786	.780	.770	.763	.756	.753	.745
110	.800	.793	.782	.777	.768	.762	.755
120	.814	.807	.797	.790	.782	.774	.763

4.13.3.2 The speed factor Cs depends on the rotational speed of the wheel and is listed in Table 4.13.3-2. These factors are obtained from the following formulas:

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

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

TABLE 4.13.3-2

SPEED FACTOR Cs

WHEEL DIA. IN INCHES	SPEED IN FEET PER MINUTE											
	30	50	75	100	125	150	175	200	250	300	350	400
8	.907	.958	1.013	1.049	1.086	1.122	1.158	1.195	1.267	1.340	1.413	1.485
9	.898	.944	1.001	1.033	1.066	1.098	1.130	1.163	1.227	1.292	1.356	1.421
10	.892	.932	.984	1.020	1.049	1.079	1.108	1.137	1.195	1.253	1.311	1.369
12	.882	.915	.958	1.001	1.025	1.049	1.074	1.098	1.146	1.195	1.243	1.292
15	.872	.898	.932	.967	1.001	1.020	1.040	1.059	1.098	1.137	1.175	1.214
18	.865	.887	.915	.944	.973	1.001	1.017	1.033	1.066	1.098	1.130	1.163
21	.860	.879	.903	.927	.952	.977	1.001	1.015	1.043	1.070	1.098	1.126
24	.857	.873	.894	.915	.937	.958	.980	1.001	1.025	1.049	1.074	1.098
27	.854	.869	.887	.906	.925	.944	.963	.982	1.012	1.033	1.055	1.076
30	.852	.865	.882	.898	.915	.932	.949	.967	1.001	1.020	1.040	1.059
36	.849	.860	.873	.887	.901	.915	.929	.944	.973	1.001	1.017	1.033

4.13.3.3 The wheel service factor Sm is equal to 1.25 times the machinery service factor Cd and is shown in the Table 4.13.3-3 for the different service classifications. This factor recognizes that the interaction between rail and wheel is more demanding in terms of durability than well aligned and lubricated interaction of machined parts.

4.13.3.4 The wheel load service coefficient Kwl = Kw × Cs × Sm with the following limitations:

Kwl may not be smaller than Kwl min. shown in Table 4.13.3-3.

4.13.3.5 The equivalent durability wheel load Pe shall be determined as follows:

P_e = Max. wheel load × Kwl the equivalent durability wheel load P_e shall not exceed wheel loads listed in Table 4.13.3-4.

4.13.4 Proper Clearance for Bridge Wheels

A total of approximately ¾ inch to one inch wider than rail head should be provided between the wheel flanges and 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.

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

TABLE 4.13.3-3

WHEEL SERVICE FACTOR Sm AND MINIMUM LOAD SERVICE FACTOR Kwl MINIMUM

CLASS OF CRANE SERVICE	A	B	C	D	E	F
Kwl MIN.	.75	.75	.8	.85	.9	.95
Sm	.8	.9	1.	1.12	1.25	1.45

TABLE 4.13.3-4

GUIDE FOR BASIC BRIDGE AND TROLLEY WHEEL LOADINGS, POUNDS. (P) (KDW)

Wheel BHN	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#	BETH & USS 175#	BETH 171#
	8	6750	8000	8500	10000							
	9	7600	9000	9500	11250	14900	15750					
	10	8450	10000	10600	12500	16550	17500					
	12		12000	12750	15000	19850	21000	22500	25500			
200	15			15950	18750	24850	25250	28150	31900			
	18			19150	22500	29800	31500	33750	38250	40500		
	21				26250	34800	35750	39400	44650	47250	65650	7350
	24					39750	42000	45000	51000	54000	75000	8400
	27							50650	57400	60750	84400	9450
	30							56250	63750	67500	93750	10500
	36								76500	81000	112500	12600
	8	8800	10400	11100	13000							
	9	9900	11700	12400	14600	19400	20500					
	10	11000	13000	13800	16250	21500	22750					
	12		15600	16600	19500	25800	27300	29250	33200			
260	15			20700	24400	32300	34100	36600	41400			
	18			24900	29250	38750	41000	43900	49700	52650		
	21				34100	45200	47800	51200	58000	61400	85300	9560
	24					51700	54600	58500	66300	70200	97500	1092
	27							65800	74600	79000	109700	1223
	30							73100	82900	87750	121900	1365
	36								99500	105300	146250	1638
	8	9400	11200	11800	13900							
	9	10600	12500	13300	15700	20800	21900					
	10	11800	13900	14800	17400	23100	24400					
320	12		16700	17800	20900	27700	29300	31300	35500			
	15			22200	26100	34600	36600	39200	44400			
	18			26700	31300	41500	43900	47000	53300	56400		
	21				36600	48400	51200	54900	62200	65800	91400	1024
	24					55400	58500	62700	71100	75200	104500	1170
	27							70500	79900	84600	117500	1317
	30							78400	88800	94000	130600	1463
	36								106600	112800	156700	1750
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	3.125	3.50

4.14 BUMPERS AND STOPS

4.14.1 Bridge bumpers - A crane shall be provided with bumpers or other means providing equivalent effect, unless the crane has a high deceleration rate due to the use of sleeve bearings, or is not operated near the ends of bridge travel, or is restricted to a limited distance by the nature of the crane operation and there is no hazard of striking any object in this limited area. These bumpers, when used, shall have the following minimum characteristics:

4.14.1.1 Have energy absorbing (or dissipating) capacity to stop the crane when traveling with power off in either direction at a speed of at least 40 percent of rated load speed.

4.14.1.2 Be capable of stopping the crane (not including load block and lifted load unless guided vertically) at a rate of deceleration not to exceed an average of 3 feet per second per second when traveling with power off in either direction at 20 percent of rated load speed.

4.14.1.3 Be so mounted that there is no direct shear on bolts upon impact.

4.14.2 Bumpers shall be designed and installed to minimize parts falling from the crane in case of breakage or loosening of bolted connections.

4.14.3 When more than one crane is located and operated on the same runway, bumpers shall be provided on their adjacent ends or on one end of one crane to meet the requirements of Sections 4.14.1.1 thru 4.14.2.

4.14.4 It is the responsibility of the owner or specifier to provide the crane manufacturer with information for bumper design. Information necessary for proper bumper design includes:

4.14.4.1 Number of cranes on runway, bridge speed, approximate weight, etc.

4.14.4.2 Height of runway stops or bumper above the runway rail.

4.14.4.3 Clearance between cranes and end of runway.

4.14.5 Runway stops are normally designed and provided by the owner or specifier and are located at the limits of the bridge travel and engage the full surface of the bumper.

4.14.6 Runway stops engaging the tread of the wheel are not recommended.

4.14.7 Trolley Bumpers - A trolley shall be provided with bumpers or other means of equivalent effect, unless the trolley is not operated near the ends of trolley travel, or is restricted to a limited distance of the bridge girder and there is no hazard of striking any object in this limited area. These bumpers, when used, shall have the following minimum characteristics:

4.14.7.1 Have energy absorbing (or dissipating) capacity to stop the trolley when traveling with power off in either direction at a speed of at least 50 percent of rated load speed.

4.14.7.2 Be capable of stopping the trolley (not including load block and lifted load unless guided vertically) at a rate of deceleration not to exceed an average of 4.7 feet per second per second when traveling with power off in either direction at ⅓ of rated load speed.

4.14.7.3 Be so mounted that there is no direct shear on bolts upon impact.

4.14.8 Bumpers shall be designed and installed to minimize parts falling from the trolley in case of breakage.

4.14.9 When more than one trolley is operated on the same bridge, bumpers shall be provided on their adjacent ends or on one end of one trolley to meet the requirements of Sections 4.14.7.1 thru 4.14.8.

4.14.10 Trolley stops shall be provided at the limit of the trolley travel, and shall engage the full surface of the bumper.

4.14.11 Trolley stops engaging the tread of the wheel are not recommended.

70-5 ELECTRICAL EQUIPMENT

5.1 GENERAL

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

Cranes for alternating current power supplies may be equipped with squirrel cage and wound rotor motors with compatible control for single speed, multi-speed or variable speed operation. Cranes for direct current power supplies, or alternating current power supply rectified on the crane, may be equipped with series, shunt or compound wound motors with compatible control for single speed or variable speed operation.

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 ANSI B30.2.0 Safety Standard for Overhead and Gantry Cranes.

5.2 MOTORS - AC and DC

5.2.1 Motors shall be designed specifically for crane and hoist duty and shall conform to NEMA Standards MG1 or AISE Standards 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 multi-speed) types.

5.2.1.2 DC motors may be series, shunt, or compound wound.

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		D.C. Motors	
Insulation Class	Open Dripproof & TEFC	TENV	Open Dripproof	TEFC & TENV
B	80 Deg. C	85 Deg. C	100 Deg. C	110 Deg. C
F	105 Deg. C	110 Deg. C	130 Deg. C	140 Deg. C
H	125 Deg. C	135 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.* DC-AISE Std. No. 1, Revised September 1968, Electrical 2. Voltage Source and 3. Field Voltage; also NEMA MGI-10.62)

TABLE 5.2.4-1

Nominal System and Motor Rated Voltage

SOURCE	DESCRIPTION	Nominal System Voltage		Motor Rated Voltage	
		AC	DC	Three Phase	Single Phase
AC	60 Hz (1) (2)	120		—	115
		208		200	—
		240		230	230
		480		460	—
		600		575	—
	50 Hz	400		380	—
	Rectified			Adjustable Voltage Shunt or Compound	
				Armature	Shunt Field
		400-3-60	460 Max. (9)	230 (4)	230 (5)
		240-3-60	(6) (9)	240	150 or 240
		460-3-60	(7) (9)	500	240 or 300
		208 thru 600	(9) 360 Max.	Constant Potential Series, Shunt, Compound	
				230 or 240 (3) (8)	
DC	Generator or Battery	—	250	230 or 240 (3) (8)	

(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 MG1-10.62B & Table 10-4 (industrial motors).

(7) NEMA MG1-10.62B & Table 10-5 (industrial motors).

(8) Rated voltage may be 250 for large frames 300 HP, 850 RPM, 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 1-12.43)

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 1-12.45.a.)

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. Performance will not necessarily be in accordance with the standards for operation at rated voltage. (Reference NEMA MG 1-12.63)

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

Unless otherwise specified by the crane manufacturer, the minimum motor time rating shall be in acccordance with Table 5.2.7-1.

TABLE 5.2.7-1 MIN. MOTOR TIME RATINGS IN MINUTES [3,4]

CMAA SERVICE CLASS	ELECTRICAL CONTROL TYPE					
	HOISTS				BRIDGES & TROLLEYS	
	AC OR DC MAGNETIC WITH MECHANICAL LOAD BRAKE	DC MAGNETIC CONSTANT POTENTIAL WITH CONTROL BRAKING	AC MAGNETIC or DC STATIC ADJ. VOLTAGE WITH CONTROL BRAKING	AC STATIC WITH FIXED SECONDARY RESISTANCE	AC OR DC MAGNETIC CONSTANT POTENTIAL	AC STATIC WITH FIXED SECONDARY RESISTANCE or DC STATIC ADJ. VOLTAGE
A	15	15	30	60	15	30
B	15	15	30	60	15	30
C	30	30	30	60	30	60
D	30 [1]	30 [1]	60 [1]	60 [1]	30 [1]	60 [1]
E	Not recommended	60 [5]	60 [2]	60 [2]	60 [2]	60 [2]
F	Not recommended	60 [5]	60 [2]	60 [2]	60 [2]	60 [2]

Note:

[1]Selection of time rating and insulation class depends on analysis of actual service requirement.

[2]Insulation class should be of a higher permissible temperature rise than the rated temperature rise of the motor. However, the temperature rise of the motor shall not exceed its rated temperature rise. The actual duty cycle of the drive should also be analyzed before final motor selection.

[3]Insulation classes shall be manufacturer's standard unless indicated otherwise.

[4]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]For D.C. drives, appropriate service factors may be applied to the motor horsepower rating for the designated time rating, in addition to the 5.2.9.1.1.2 K_C factor, to attain adequate thermal dissipating ability, with control designed accordingly.

5.2.8 Squirrel cage motors shall have high starting torque, low starting current and high slip at full load, similar to NEMA Design D, unless otherwise specified by the crane manufacturer.

5.2.9 Motor size selection: The motor size selection involves torque and thermal considerations.

5.2.9.1 The motor rating of any drive, hoist or horizontal travel, using either AC or DC power, is basically the mechanical horsepower with considerations for the effect of control, ambient temperature, and service class.

5.2.9.1.1 Hoist Drives

5.2.9.1.1.1 Mechanical Horsepower

$$\text{Mechanical HP} = \frac{W \times V}{33000 \times E}$$

W = total weight in pounds to be lifted by the hoist drive rope system. This includes all items applicable to the hoist such as the purchaser's lifted load, which includes purchaser furnished attachments and crane manufacturers furnished items including the hook block and attachments.

V = specified speed in feet per minute when lifting weight W

E = mechanical efficiency between the load and the motor, expressed in decimal form, where:

$$E = E_g^n \times E_s^m$$

Eg = efficiency per gear reduction.

n = number of gear reductions.

Es = rope system efficiency per rotating sheave.

m = the number of rotating sheaves between drum and equalizer passed over by each part of the moving rope attached to the drum.

TABLE 5.2.9.1.1.1-1

Typical Efficiency Values		
Bearings	Eg*	Es
Anti-friction	.97	.99
Sleeve	.93	.98

*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.

HOIST MECHANICAL EFFICIENCY

The tabulated values of overall hoist mechanical efficiency, E, as defined for anti-friction sheave bearings are shown in the following Table 5.2.9.1.1.1-2.

TABLE 5.2.9.1.1.1-2

HOIST OVERALL MECHANICAL EFFICIENCY

Total Number of Ropes Supporting One Hook Block		Total Number of Rotating Sheaves for Each Rope Off Drum m	Efficiency of Ropes Only $(E_S)^m$	Overall Combined Efficiency, E	
Double Reeved	Single Reeved		$(.99^m)$	2 Gear Reductions n = 2 Eg^n = .9409	3 Gear Reductions n = 3 Eg^n = .9127
4	2	1	.990	.931	.903
6	3	2	.980	.922	.894
8	4	3	.970	.913	.885
10	5	4	.960	.904	.877
12	6	5	.951	.895	.868
14	7	6	.941	.886	.859
16	8	7	.932	.877	.850
18	9	8	.922	.868	.842
20	10	9	.913	.859	.834
22	11	10	.904	.851	.825
24	12	11	.895	.842	.817
26	13	12	.886	.834	.809
28	14	13	.877	.826	.801
30	15	14	.869	.817	.793
32	16	15	.860	.809	.785
34	17	16	.851	.801	.777
36	18	17	.843	.793	.769
38	19	18	.834	.785	.761
40	20	19	.826	.777	.754
42	21	20	.818	.769	.746

5.2.9.1.1.2 Required Motor Horsepower:

The hoist motor shall be selected so that its horsepower rating should not be less than that given by the following formula:

Required rated horsepower = Mechanical horsepower × Kc

where Kc = Control factor, which is a correction value that accounts for the effects the control has on motor torque and speed.

Kc = 1 for the majority of controls such as AC wound rotor magnetic or static systems where there are no secondary permanent slip resistors, systems for squirrel cage motors, and constant potential magnetic systems with DC Power shop supplies.

For AC wound rotor systems, magnetic or static control, with secondary permanent slip resistors.

$$Kc = \frac{\text{motor rated full load RPM}}{\text{*motor operating RPM, when hoisting}}$$

*At rated torque with permanent slip resistors

Kc values for power supplies rectified on the crane, for use with DC motors, magnetic or static control systems, shall be determined by consultation with the motor and control manufacturers.

The methods described for hoist motor horsepower selection are recommended for use through CMAA Class D. For Classes E and F, due consideration shall also be given to the thermal effects caused by the service. For example, this may require larger frame, larger horsepower, forced cooling, etc.

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

5.2.9.1.2 Bridge and Trolley Drives

5.2.9.1.2.1 Indoor Cranes: Bridge and Trolley

Required Motor Horsepower:

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

HP = Ka × W × V × Ks
Ka = acceleration factor for type of motor used
Ks = service factor which accounts for the type of drive and duty cycle. For reference see Table 5.2.9.1.2.1-E
W = total weight to be moved including all dead and live loads in tons
V = rated drive speed in feet per minute

For the general case of bridge and trolley drives:

$$Ka = \frac{f + \dfrac{2000a \times Cr}{g \times E}}{33{,}000 \times Kt} \times \frac{Nr}{Nf}$$

f = rolling friction of drive (including transmission losses) in pounds per ton) (Ref. Table 5.2.9.1.2.1-D)
a = average or equivalent uniform acceleration rate in feet per second per second up to rated motor RPM. For guidance, see Table 5.2.9.1.2.1-A and Table 5.2.9.1.2.1-B
Cr = 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. (suggest use of .9 if efficiency is unknown).
Nr = rated speed of motor in RPM at full load.
Nf = free running RPM of motor when driving at speed V (see also Section 5.2.10.2)
Kt = equivalent steady state torque relative to rated motor torque which results in accelerating up to rated motor RPM (Nr) in the same time as the actual variable torque speed characteristic of the motor and control characteristic used. See Table 5.2.9.1.2.1-C for typical values of Kt.

TABLE 5.2.9.1.2.1-A

Guide for Travel 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
360	6.0	.60 - 1.1
420	7.0	.70 - 1.2
480	8.0	.80 - 1.3
540	9.0	.90 - 1.4
600	10.0	1.0 - 1.6

Note[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 rate shall not exceed the values shown in Table 5.2.9.1.2.1-B to avoid wheel skidding.

Note[2] - For D.C. series motors the acceleration rate 'a' is the value occurring while on series resistors. This would be in the range of 50 to 80 percent of the free running speed (Nf).

TABLE 5.2.9.1.2.1-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

TABLE 5.2.9.1.2.1-C

RECOMMENDED VALUES OF K_T (ACCELERATING TORQUE FACTOR)

Type of Motor	Type of Control	[1]K_T
AC Wound Rotor	Contactor-Resistor	1.3-1.5[2]
AC Wound Rotor	Static Stepless	1.3-1.5[2]
AC Wound Rotor, Mill	Contactor-Resistor	1.5-1.7[2]
AC Sq Cage	Ballast Resistor	1.3
DC Shunt Wound	Adjustable Voltage	1.5
DC Series Wound	Contactor-Resistor	1.35

[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 5.2.9.1.2.1-D

Suggested Values for f (Friction Factor)
For Bridges & Trolleys with Metallic Wheels
& Anti-Friction Bearings

Wheel Dia. Inches	36	30	27	24	21	18	15	12	10	8	6
Friction Lb/Ton(f)	10	10	12	12	12	15	15	15	15	16	16

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.

TABLE 5.2.9.1.2.1-E
Recommended Values of Travel Drive Service Class Factor Ks[3]

CMAA Service Class	DC Constant Potential w/AISE Series Mill Mtrs[4]		AC Magnetic	AC Static with fixed Secondary Resistance (Permanent Slip)
	60 Minutes	30 Minutes	Adjustable Voltage with DC Shunt Motors	
A	.75	1.0	1.0	1.2
B	.75	1.0	1.0	1.2
C	.75	1.0	1.0	1.2
D	.85	1.15	1.1	1.3
E[1]	1.0	N/A	1.2	1.4
F[2]	1.4	N/A	1.4	1.6

[1]The recommended values shown for Class E are based on a maximum of 30 percent time on and a maximum of 25 cycles per hour of the drive. A cycle for a bridge or trolley consists of two (2) moves (one (1) loaded and one (1) unloaded). For drive duty higher than this basis, it is recommended that duty cycle methods of analysis be used.

[2]The recommended values shown for Class F are based on a maximum of 50 percent time on and a maximum of 45 cycles per hour of the drive. A cycle for a bridge or trolley consists of two (2) moves (one (1) loaded and one (1) unloaded). For drive duty higher than this basis, it is recommended that duty cycle methods of analysis be used.

[3]For recommended values of Ks for controls not shown, consult crane manufacturer.

[4]For industrial type D.C. motors, consult crane manufacturer.

5.2.9.1.2.2 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.

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

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

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

where W = full load weight to be accelerated in tons.

V = full load speed in feet per minute.

f = friction factor = pounds per Table 5.2.9.1.2.1-D

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

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

where: P = wind pressure in pounds per square foot computed from the formula $P = .004\,(Vw)^2$ where Vw is the wind velocity in miles per hour.

when Vw 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 in feet per minute.

E = bridge drive mechanical efficiency.

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

Required motor horsepower = 0.75 (HPF + HPw) Ks

using HPF and HPw as computed above.
where: Ks = service class factor utilized per Table 5.2.9.1.2.1-E

5.2.9.1.2.3.4 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 as defined in Section 4.9.4.

5.2.9.1.2.4 Outdoor Cranes: Trolley drive motor horsepower shall use same selection procedure as indoor cranes per section 5.2.9.1.2.1.

5.2.10 The gear ratio should be selected to provide the specified drive speed with rated load on the hook, for the actual motor and control system used.

5.2.10.1 Hoist Drive Gear Ratio.

$$\text{Hoist drive gear ratio} = \frac{Nf \times D \times \pi}{R \times V \times 12}$$

where: Nf = free running motor RPM when hoisting rated load W (lbs) at speed V (FPM) the value Nf is established from the motor-control speed-torque curves at the full load hoisting (HP FL).

$$\text{HP FL} = \frac{W \times V}{33000 \times E}$$

E = mechanical efficiency per 5.2.9.1.1.1.

D = drum pitch diameter in inches.

V = specified full load hoisting speed in FPM

$$R = \text{rope reduction ratio} = \frac{\text{total number of ropes supporting the load block}}{\text{number of ropes from the drum(s)}}$$

5.2.10.2 Travel Drive Gear Ratios—Bridge and Trolley.

$$\text{Bridge or trolley drive gear ratio} = \frac{Nf \times Dw \times \pi}{V \times 12}$$

Nf = free running RPM of the motor, after the drive has accelerated, with rated load to the steady state speed V. The value of Nf is established from the motor-control speed-torque curves at the free running horsepower (HP FR)

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

where: W = total load in tons.
f = rolling friction in pounds per ton reference Table 5.2.9.1.2.1-D
V = specified full load travel drive speed in feet per minute.
Dw = wheel tread diameter in inches.

5.2.10.3 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 hoist and traverse motions shall be specified by the crane manufacturer.

5.3.2 Refer to Section 4.9 of this specification for brake selection and rating.

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

5.3.4 On hoists equipped with two electric holding brakes, a time delay setting of one brake may be included.

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

5.3.6 Brake coil time rating shall be selected for the duration and frequency of operation required by the service. Any electrical traverse drive brake used only for emergency stop on power loss or setting by operator choice shall have a coil rated for continuous duty.

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 crane hoist and travel motors. Other control requirements such as protection and master switches are covered in other sections.

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 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, variable frequency, and adjustable or variable voltage.

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 include 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, and 5.4.5.2-3 DC. 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.

TABLE 5.4.5.2-1

AC CONTACTOR RATINGS FOR WOUND ROTOR MOTORS

Size of Contactor	8-hour Open Rating, Amperes	Maximum Intermittent Rating**		
		Amperes*	Horsepower at	
			230 Volts	460 and 575 Volts
0	20	20	3	5
1	30	30	7½	10
2	50	67	20	40
3	100	133	40	80
4	150	200	63	125
5	300	400	150	300
6	600	800	300	600
7	900	1200	450	900
8	1350	1800	600	1200

*The ultimate trip current of overload (overcurrent) relays or other motor protective devices used shall not exceed 115 percent of these values or 125 percent of the motor full load current, whichever is smaller.

**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 1½ 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 & 575 Volts
0	3	5
1	7½	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**

Size of Contactor	8-hour Open Rating, Amperes	Maximum Intermittent Rating	
		Amperes	Horsepower
1	25	30	7½
2	50	67	15
3	100	133	35
4	150	200	55
5	300	400	110
6	600	800	225
7*	900	1200	330
8*	1350	1800	500
9*	2500	3330	1000

*Resistor stepping contactors may be rated for the actual current carried.

**For constant potential D.C. drives other than 230 to 250 volts, refer to NEMA ICS 3-443.20.3.

For adjustable voltage D.C. 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 A.C. wound rotor motors and D.C. 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 CONTROLS

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,E,F	A,B	C	D,E,F	A,B	C	D,E,F
	FOR A.C. 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
31 thru 75	4	4	4	1	3	3	5	5	5
76 thru 125	5	5	5	1	4	4	6	6	6
126 thru 200	5	5	5	4	4	4	6	6	6
Greater than 200	6	6	6	5	5	5	7	7	7
	FOR A.C. WOUND ROTOR SECONDARY RESISTOR FLOOR CONTROL CRANES								
Less than 30	2	2	3	1	1	2	3	3	4
Greater than 30	Same as for cab control cranes								
	FOR D.C. 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
36 thru 55	3	4	4	1	3**	3**	4	5	5
56 thru 110	4	4	4	3**	3**	3**	5	5	5
Greater than 110	5	5	5	4**	4**	4**	6	6	6
	FOR D.C. 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								

Notes to Table continue on next page.

Foot Notes to Table 5.4.5.3-1

*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,D,E and F, 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 A.C. 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 point 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 multi-pole 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 1A — General purpose—Indoor-Gasketed.
(Note: Type 1-A enclosure is not currently recognized by NEMA)
Type 2 — Dripproof—Indoor.
Type 3 — Dusttight, raintight and sleet-resistant, ice-resistant—Outdoor.
Type 3R — Rainproof and sleet-resistant, ice-resistant—Outdoor.
Type 3S — Dusttight, raintight and sleet (Ice-) proof—Outdoor.
Type 4 — Watertight and dusttight—Indoor and Outdoor.
Type 4X — Watertight, dusttight and corrosion-resistant—Indoor and Outdoor.
Type 12 — Industrial Use—Dusttight and driptight—Indoor.
Type 13 — Oiltight and dusttight—Indoor.

ENCLOSURES FOR HAZARDOUS LOCATIONS

Type 7 — Class I, Division I, Group A, B, C, or D—Indoor Hazardous Locations—Air-break Equipment.
Type 9 — Class II, Division I, 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, if 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 classes D, E, and F.

5.5.2 Resistors used with power electrical braking systems on A.C. 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 CONTACTOR RATINGS for Mainline Service

Size of Contactors	8-hour Open rating *Amperes*	Maximum Intermittent Duty Rating Amperes*	*Maximum Total Motor Horsepower*		*Maximum Horsepower for any Motion*	
			230V	460 & 575V	230V	460 & 575V
0	20	20	6	6	3	5
1	30	30	10	20	7½	10
2	50	67	30	60	20	40
3	100	133	63	125	40	80
4	150	200	110	225	63	125
5	300	400	225	450	150	300
6	600	800	450	900	300	600
7	900	1200	675	1350	450	900
8	1350	1800	900	1800	600	1200

*The *ultimate trip current* of overload (overcurrent) relays or other motor protective devices used shall not exceed 115 percent of these values or 125 percent of the motor full load current, whichever is smaller.

TABLE 5.6.6-2

RATINGS AT 230 to 250 VOLTS OF DC CONTACTORS for Mainline Service

Size of Contactors	8-hour Open rating Amperes	Maximum Intermittent Duty Rating Amperes	*Maximum Total* Motor Horsepower	*Maximum Horsepower* for any Motion
1	25	30	10	7½
2	50	67	22	15
3	100	133	55	35
4	150	200	80	55
5	300	400	160	110
6	600	800	320	225
7	900	1200	480	330
8	1350	1800	725	500
9	2500	3330	—	—

5.6.7 Motor running overcurrent protection shall be provided in accordance with NEC 610-43 Motor Running Overcurrent 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 An automatically reset instantaneous trip overload relay set at approximately 200 percent of the hoist motor full load current shall be furnished for D.C. hoists. Devices offering equivalent motor torque limitation may be used in lieu of the overload relay.

5.6.11 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.

5.6.12 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.

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

5.6.14 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.

5.6.15 Warning Devices

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

5.6.15.2 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.

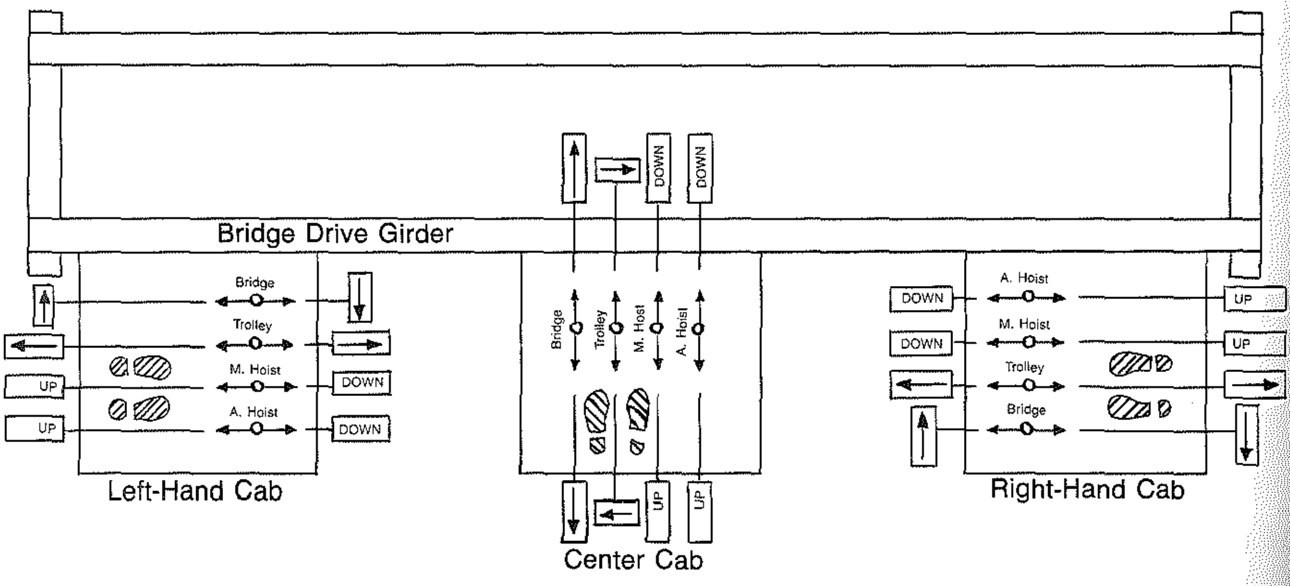
5.7.4 The arrangement of master switches should conform to Figures 5.7.3a and 5.7.3b, unless otherwise specified.

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

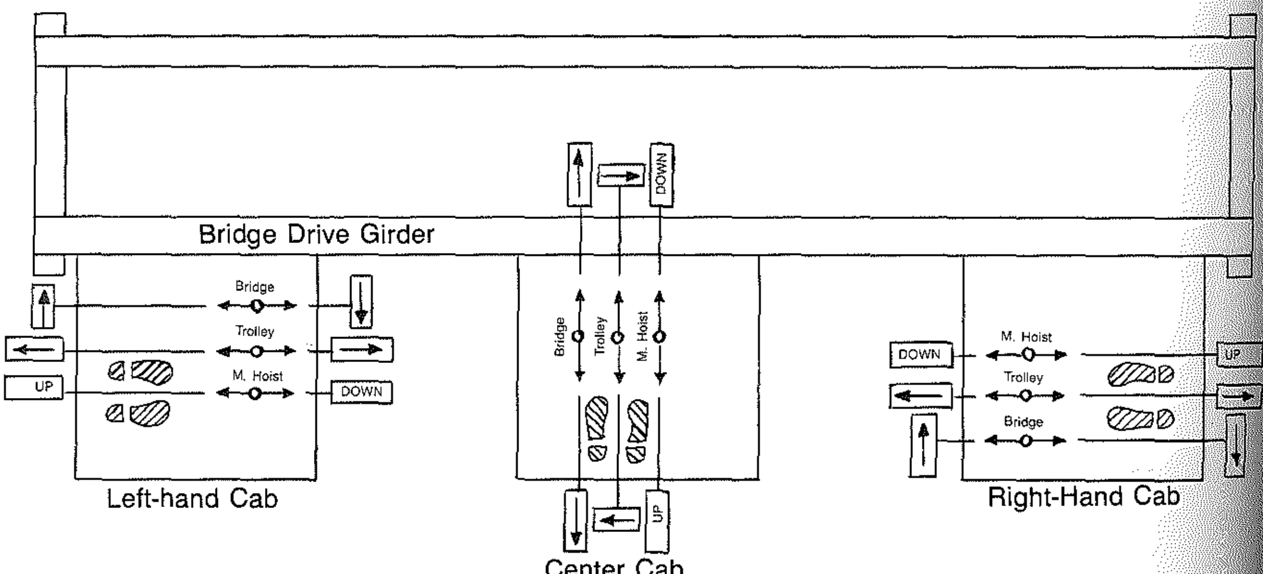
5.7.8 Master switches shall be clearly labeled to indicate their functions.



4 Motor Crane

RECOMMENDED ARRANGEMENT OF CONTROLLERS

Fig. 5.7.3a



3 Motor Crane

RECOMMENDED ARRANGEMENT OF CONTROLLERS

Fig. 5.7.3b

5.8 FLOOR OPERATED PENDANT PUSHBUTTON STATIONS

5.8.1 The arrangement of pendant pushbutton stations and radio transmitters should conform to Figures 5.8.1a, 5.8.1b., or 5.8.1c.

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.

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.

Pendant Pushbutton Station Arrangements

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

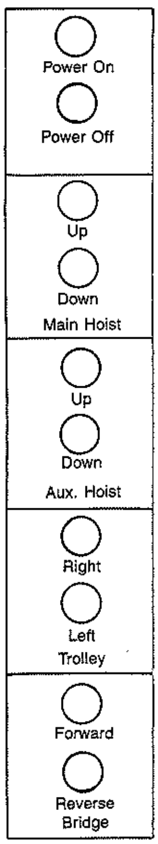


Fig. 5.8.1a

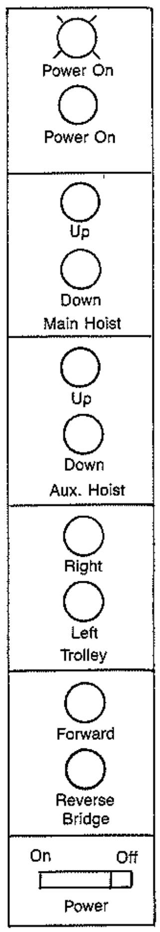
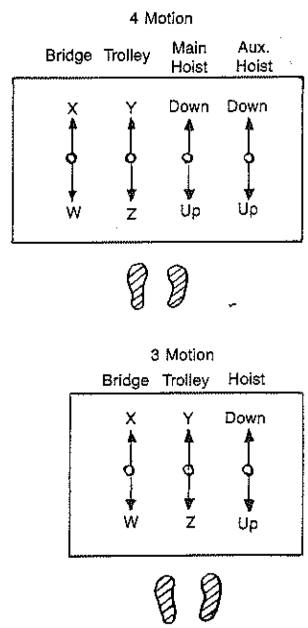


Fig. 5.8.1b

Radio Crane 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.

Fig. 5.8.1c

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 manufacturers 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.

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.

5.12 RUNWAY CONDUCTOR SYSTEMS

5.12.1 Refer to Section 1.5 of 70-1 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 collectors for each runway conductor shall be furnished when the crane is used with a lifting magnet.

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 to 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 the 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 voltage.

5.14.5 The actual 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.)

70-6 RECOMMENDED CRANE INQUIRY DATA SHEET

Fig. 6.1

Customer ______________________________

____

Spec No. ______________________________

Date ______________________________

---

1. Number Cranes Required __________.

2. Capacity: Main Hoist __________ Tons Aux. Hoist __________ Tons Bridge __________ Tons

3. Required Hook Lift (Max. Including Pits or Wells Below Floor Elevation)

   Main Hoist __________ Ft. __________ In. Aux. Hoist __________ Ft. __________ In.

4. Approximate Length of Runway __________ Ft.

5. Number of Cranes on Runway __________.

6. Service Information: C.M.A.A. Class __________ (See Section 70-2)

   Main Hoist: Average Lift __________ Ft. Number of Lifts per Hour __________ Speed __________ F.P.M.

   Hours per Day __________ Hook __________ Magnet __________ Bucket __________

   Give Size & Weight of Magnet or Bucket ______________________________

   Aux. Hoist: Average Lift __________ Ft. Number of Lifts per Hour __________ Speed __________ F.P.M.

   Hours per Day __________ Hook __________ Magnet __________ Bucket __________

   Give Size & Weight of Magnet or Bucket ______________________________

   Bridge: Number Moves per Hour __________ Hours per Day __________ Speed __________ F.P.M.

   Average Movement ______________________________

   Trolley: Number of Moves per Hour __________ Hours per Day __________ Speed __________ F.P.M.

   Average Movement ______________________________

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

   ____

   ____

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

9. Material Handled ______________________________

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

11. Power: Volts ________ Phase ________ Hertz ________ A.C., Volts ________ D.C.

12. Method of Control: Cab ________ Floor ________ Other ________

13. Location of Control: End of Crane ________ Center ________ On Trolley ________

Other ________

14. Type of Control (Give complete information, including number of speed points) Ref. 5.4.4

Main Hoist ________

Auxiliary Hoist ________

Trolley ________

Bridge ________

15. Type of Control Enclosure: (Ref. 5.4.7.1) ________

16. Type of Motors: (Give complete information) ________

____

17. Must wiring comply with Special Conditions or Codes ________

Describe briefly (See Items 7 & 8) ________

____

18. Bridge Conductor Type: ________

19. Runway Conductor Type: Insulated ________ (MFR) ________

Bare Wires ________ Angles ________ Other ________

Furnished By: ________

20. List of Special Equipment or Accessories Desired ________

____

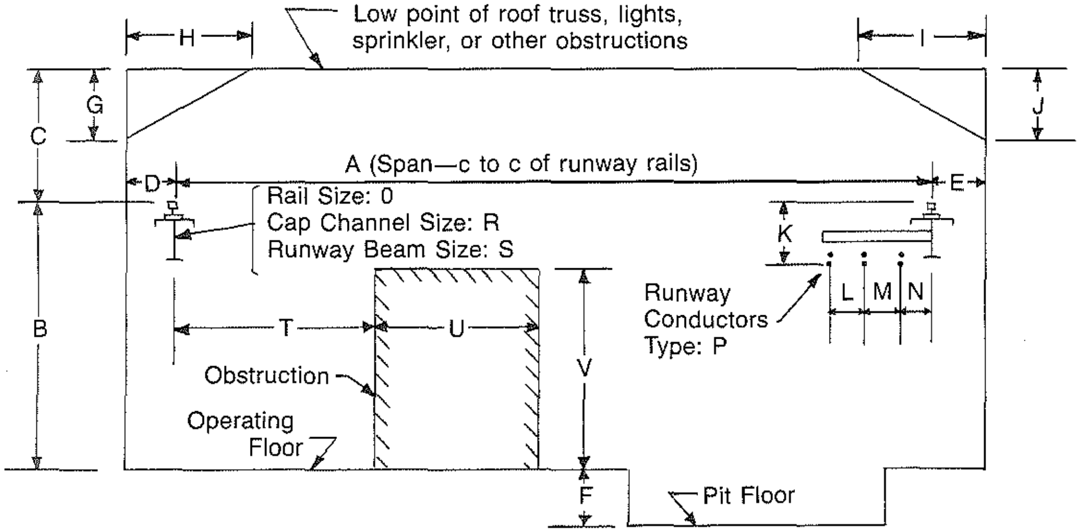
21. For special cranes with multiple hooks or trolley or other unique requirements, provide detailed information on hook spacing, orientation, capacities, and total bridge capacity.

____

____

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.

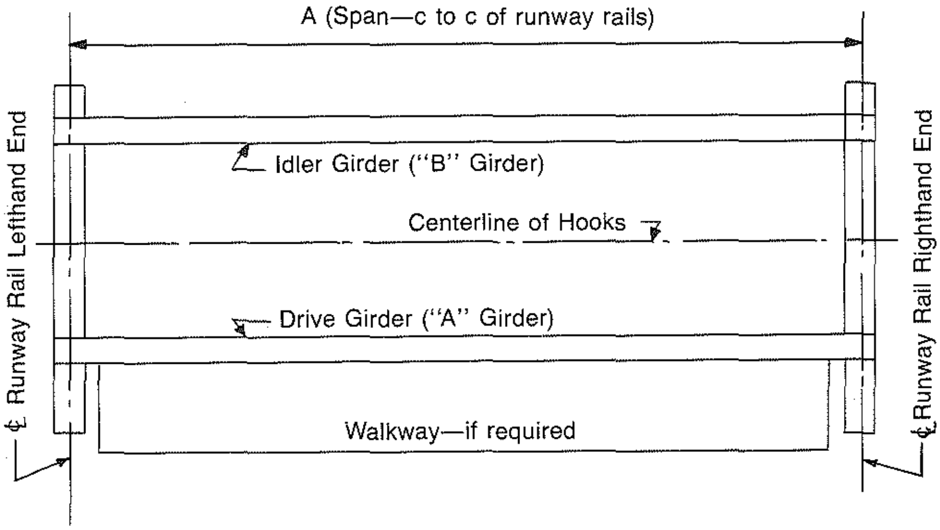
CLEARANCES: Complete the building drawing below making special note of any obstructions which may interfere with the crane including special clearance requirements under girders or cab.



E L E V A T I O N

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

Indicate the "North" direction, cab or pendant location, relative locations of main and auxiliary hook, runway conductor location, adjacent cranes, etc.



P L A N

Fig. 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
35	7	12	25	50	80	125	50	115	150
40	7	12	25	40	70	100	40	100	150
50	5	11	20	40	70	100	40	100	150
60	5	9	18	40	70	100	40	75	125
75	4	9	15	40	70	100	30	75	125
100	4	8	13	30	60	80	25	50	100
150	3	6	11	25	60	80	25	50	100

NOTE: Consideration must be given to length of runway for the bridge speed, span of bridge for the trolley speed, distance average travel, and spotting characteristics required.

Fig. 6.3
SUGGESTED OPERATING SPEEDS
FEET PER MINUTE
CAB CONTROLLED CRANES

CAPACITY IN TONS	HOIST			TROLLEY			BRIDGE		
	SLOW	MEDIUM	FAST	SLOW	MEDIUM	FAST	SLOW	MEDIUM	FAST
3	14	35	45	125	150	200	200	300	400
5	14	27	40	125	150	200	200	300	400
7.5	13	27	38	125	150	200	200	300	400
10	13	21	35	125	150	200	200	300	400
15	13	19	31	125	150	200	200	300	400
20	10	17	30	125	150	200	200	300	400
25	8	14	29	100	150	175	200	300	400
30	7	14	28	100	125	175	150	250	350
35	7	12	25	100	125	150	150	250	350
40	7	12	25	100	125	150	150	250	350
50	5	11	20	75	125	150	100	200	300
60	5	9	18	75	100	150	100	200	300
75	4	9	15	50	100	125	75	150	200
100	4	8	13	50	100	125	50	100	150
150	3	6	11	30	75	100	50	75	100

NOTE: Consideration must be given to length of runway for the bridge speed, span of bridge for the trolley speed, distance average travel, and spotting characteristics required.

ABNORMAL OPERATING CONDITIONS: Environmental conditions that are unfavorable, harmful or detrimental to or for the operation of a hoist, such as excessively high (over 100 deg. F.) or low (below 0 deg. F.) ambient temperatures, corrosive fumes, dust laden or moisture laden atmospheres, and hazardous locations.

ADJUSTABLE OR VARIABLE VOLTAGE: A method of control by which the motor supply voltage can be adjusted.

AUTOMATIC CRANE: A crane which when activated operates through a perset cycle or cycles.

AUXILIARY HOIST: A supplemental hoisting unit, usually designed to handle lighter loads at a higher speed than the main hoist.

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 anti-friction bearing is the minimum expected life, hours, of 90 percent 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.

BHN: Brinell hardness number, measurement of material hardness.

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

BRAKE: A device, other than a motor, used for retarding or stopping motion by friction or power means. (See Section 4.9)

BRANCH CIRCUIT: The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).

BRIDGE: That part of an overhead crane consisting of girders, trucks, end ties, 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.

BRIDGE RAIL: The rail supported by the bridge girders on which the trolley travels.

BUMPER (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 handle.

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

CMAA: Crane Manufacturers Association of America (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 electro-magnetic device for opening and closing an electric power circuit.

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

COUNTER-TORQUE: A method of control by which the motor is reversed to develop power to the opposite direction.

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

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

CUSHIONED START: An electrical or mechanical method for reducing the rate of acceleration of a travel motion.

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 the member.

DRIVE GIRDER: The girder on which the bridge drive machinery is mounted.

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.

DYNAMIC LOWERING: A method of control by which the hoist motor is so connected in the lowering direction, that when it is over-hauled by the load, it acts as a generator and forces current either through the resistors or back into the line.

EDDY-CURRENT BRAKING: A method of control by which the motor drives through an electrical induction load brake.

EFFICIENCY OF GEARING AND SHEAVES: The percentage of force transmitted through these components that is not lost to friction.

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 TIE: A structural member other than the end truck which connects the ends of the girders to maintain the squareness of the bridge.

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

FAIL-SAFE: A provision designed to automatically stop or safely control any motion in which a malfunction occurs.

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 an independent platform.

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

GANTRY CRANE: A crane similar to an overhead crane except that the bridge for carrying the trolley or trolleys is rigidly supported on two or more legs running on fixed rails or other runway.

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

GROUND FAULT: An accidental conducting connection between the electrical circuit or equipment and the earth or some conducting body that serves in place of the earth.

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.

HYDRAULIC BRAKE: A brake that provides retarding or stopping motion by hydraulic means.

IDLER SHEAVE: A sheave used to equalize tension in opposite parts of a rope. Because of its slight movement, it is not termed a running sheave.

IMPACT ALLOWANCE: Additional hook load assumed to result from the dynamic effect of the live load.

INDUSTRIAL DUTY CRANE: Service classification covered by CMAA Specification No. 70, 'Specifications for Electric Overhead Traveling Cranes'.

INSULATION CLASS: Motor winding insulation rating which indicates its ability to withstand heat and moisture.

K.S.I.: 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.

LATERAL FORCES: Horizontal forces perpendicular to the axis of the member being considered.

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

LIFT CYCLE: Single lifting and lowering motion (with or without load).

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 BLOCK: The assembly of hook, swivel, bearing, sheaves, pins and frame suspended by the hoisting ropes.

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

LOAD CYCLE: One lift cycle with load plus one lift cycle without load.

LONGITUDINAL STIFFENERS: Horizontal members attached to the web of the bridge girder to prevent web buckling.

MAGNETIC CONTROL: A means of controlling direction and speed by using magnetic contactors and relays.

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

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

MANUAL-MAGNETIC DISCONNECT SWITCH: A power disconnecting means consisting of a magnetic contactor that can be operated by remote pushbutton and can be manually operated by a handle on the switch.

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.

MECHANICAL LOAD BRAKE: An automatic type of friction brake used for controlling loads in the lowering direction. This unidirectional device requires torque from the motor to lower a load but does not impose additional load on the motor when lifting a load.

MEAN EFFECTIVE LOAD: A load used in durability calculations accounting for both maximum and minimum loads.

MILL DUTY CRANE: Service classification covered by AISE Standard No. 6, 'Specification for Electric Overhead Traveling Cranes for Steel Mill Service'.

MULTIPLE GIRDER CRANE: A crane which has two or more girders for supporting the live load.

NON-COASTING MECHANICAL DRIVE: A drive with coasting characteristics such that it will stop the motion within a distance in feet equal to 10 percent of the rated speed in feet per minute when traveling at rated speed with rated load.

OPERATOR'S CAB: The operator's compartment from which movements of the crane are controlled. To be specified by the manufacturer as open, having only sides or a railing around the operator, or enclosed, complete with roof, windows, etc.

OVERLOAD: Any load greater than the rated load.

OVERLOAD LIMIT DEVICE: Refer to Section 4.3 for a complete definition.

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

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

PITCH DIAMETER (ROPE): Distance through the center of a drum or sheave from center to center of a rope passed about the periphery.

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

PLUGGING: A control function which accomplishes braking by reversing the motor line voltage polarity or phase sequence.

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

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

RATED LOAD: The maximum load which the crane is designed to handle safely as designated by the manufacturer.

REGENERATIVE BRAKING: A method of controlling speed in which electrical energy generated by the motor is fed back into the power system.

REGULATED SPEED: A function which tends to maintain constant motor speed for any load for a given speed setting of the controller.

REMOTE OPERATED CRANE: A crane controlled by an operator not in a pulpit or in the cab attached to the crane, by any method other than pendant or rope control.

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

ROTATING AXLE: An axle which rotates with the wheel.

RUNNING SHEAVE: A sheave which rotates as the hook is raised or lowered.

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 supplies current to the crane.

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

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

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

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

SKELETON CAB: Same as dummy cab.

SKEWING FORCES: Lateral forces on the bridge truck wheels caused by the bridge girders not running perpendicular to the runways. Some normal skewing occurs in all bridges.

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

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

STEPLESS CONTROL: A type of control system with infinite speed control between minimum speed and full speed.

STEPPED CONTROL: A type of control system with fixed 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.

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

TEFC: Totally enclosed fan cooled.

TENV: Totally enclosed non ventilated.

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

TORSIONAL BOX GIRDER: Girder in which the trolley rail is located over one web.

TORSIONAL FORCES: Forces which can cause twisting of a member.

TROLLEY: The unit carrying the hoisting mechanism which travels on the bridge rails.

TROLLEY FRAME: The basic structure of the trolley on which are mounted the hoisting and traversing mechanisms.

TWO BLOCKING: Condition under which the load block or load suspended from the hook becomes jammed against the crane structure preventing further winding up of the hoist drum.

UNDERVOLTAGE 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 frequency can be adjusted.

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

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

WHEELBASE: Distance from center-to-center of outermost wheels.

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

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