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

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

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

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

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, i.e., $P/(d \times L)$ 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 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 0.001 inches per inch of diameter or a total of 0.010 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 VIF. When sizing wheels and rails, the following parameters shall be considered:

$D$ = wheel diameter $(in)$

$W$ = effective rail head width $(in)$

$K$ = hardness coefficient of the wheel

where: $K = BHN \times 5$ (for wheels with $BHN \le 260$)

$K = 1300(BHN/260)^{0.33}$ (for wheels with $BHN > 260$)

The basic bridge and trolley recommended durability wheel loading for different wheel hardness and size 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, $K_{wtw}$ or $K_{wbw}$, the speed factor $C_s$, and the crane service class shall be considered.

**TABLE 4.13.3-1**

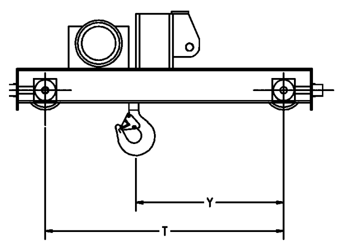
**TYPICAL BRIDGE LOAD FACTORS $K_{wbw}$**

| CAPACITY IN TONS | BRIDGE SPAN IN FEET | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| 3 | 0.812 | 0.817 | 0.827 | 0.842 | 0.861 | 0.877 | 0.888 | 0.898 | 0.912 | 0.926 | 0.934 |
| 5 | 0.782 | 0.785 | 0.794 | 0.809 | 0.830 | 0.844 | 0.857 | 0.869 | 0.883 | 0.890 | 0.909 |
| 7.5 | 0.762 | 0.767 | 0.777 | 0.791 | 0.807 | 0.825 | 0.835 | 0.850 | 0.867 | 0.882 | 0.894 |
| 10 | 0.747 | 0.750 | 0.760 | 0.771 | 0.790 | 0.807 | 0.818 | 0.832 | 0.848 | 0.863 | 0.879 |
| 15 | 0.732 | 0.736 | 0.744 | 0.758 | 0.773 | 0.789 | 0.802 | 0.815 | 0.826 | 0.844 | 0.860 |
| 20 | 0.722 | 0.725 | 0.732 | 0.740 | 0.754 | 0.768 | 0.779 | 0.792 | 0.806 | 0.823 | 0.834 |
| 25 | 0.716 | 0.718 | 0.723 | 0.738 | 0.747 | 0.760 | 0.770 | 0.782 | 0.796 | 0.812 | 0.827 |
| 30 | 0.716 | 0.718 | 0.723 | 0.731 | 0.741 | 0.752 | 0.761 | 0.774 | 0.786 | 0.800 | 0.814 |
| 35 | 0.714 | 0.715 | 0.722 | 0.728 | 0.736 | 0.746 | 0.754 | 0.767 | 0.780 | 0.793 | 0.807 |
| 40 | 0.713 | 0.713 | 0.717 | 0.723 | 0.729 | 0.738 | 0.746 | 0.758 | 0.770 | 0.782 | 0.797 |
| 50 | 0.713 | 0.711 | 0.714 | 0.720 | 0.726 | 0.734 | 0.742 | 0.754 | 0.763 | 0.777 | 0.790 |
| 60 | 0.709 | 0.708 | 0.711 | 0.716 | 0.722 | 0.729 | 0.738 | 0.747 | 0.756 | 0.768 | 0.782 |
| 75 | 0.709 | 0.708 | 0.711 | 0.715 | 0.721 | 0.727 | 0.735 | 0.744 | 0.753 | 0.762 | 0.774 |
| 100 | 0.708 | 0.706 | 0.708 | 0.711 | 0.717 | 0.723 | 0.730 | 0.737 | 0.745 | 0.755 | 0.763 |

4.13.3.1. The load factor $K_{wtw}$ for trolley wheels is established by the following formula:

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

where: $TW$ = trolley weight



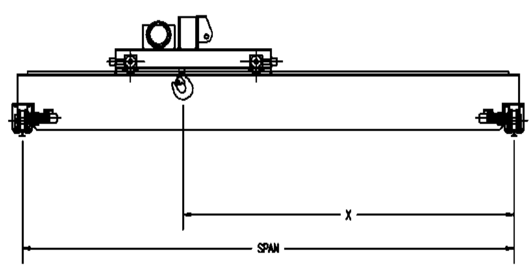

The load factor $K_{wbw}$ for bridge wheels is established by the following formula or Table 4.13.3-1 may be used for standard hook cranes in lieu of calculating the exact value for a particular application. Other cranes may require special considerations. The factors shown at 120-ton capacity may be used for capacities above 120 tons.

$$K_{wbw} = \frac{0.75(BW) + f(LL) + 0.5(TW) - 0.5f(TW)}{0.75(BW) + 1.5f(LL)}$$

where: $BW$ = bridge weight

$LL$ = trolley weight + rated load

$f$ = $X$ / span



4.13.3.2. The speed factor $C_s$ 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:

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

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

## TABLE 4.13.3-2

## SPEED FACTOR $C_s$

| WHEEL DIA. $(in)$ | SPEED $(ft/min)$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 250 | 300 | 350 | 400 |
| 8 | 0.90 | 0.95 | 1.01 | 1.04 | 1.08 | 1.12 | 1.15 | 1.19 | 1.26 | 1.34 | 1.41 | 1.485 |
| 9 | 0.89 | 0.94 | 1.00 | 1.03 | 1.06 | 1.09 | 1.13 | 1.16 | 1.22 | 1.29 | 1.35 | 1.421 |
| 10 | 0.89 | 0.93 | 0.98 | 1.02 | 1.04 | 1.07 | 1.10 | 1.13 | 1.19 | 1.25 | 1.31 | 1.369 |
| 12 | 0.88 | 0.91 | 0.95 | 1.00 | 1.02 | 1.04 | 1.07 | 1.09 | 1.14 | 1.19 | 1.24 | 1.292 |
| 15 | 0.87 | 0.89 | 0.93 | 0.96 | 1.00 | 1.02 | 1.04 | 1.05 | 1.09 | 1.13 | 1.17 | 1.214 |
| 18 | 0.86 | 0.88 | 0.91 | 0.94 | 0.97 | 1.00 | 1.01 | 1.03 | 1.06 | 1.09 | 1.13 | 1.163 |
| 21 | 0.86 | 0.87 | 0.90 | 0.92 | 0.95 | 0.97 | 1.00 | 1.01 | 1.04 | 1.07 | 1.09 | 1.126 |
| 24 | 0.85 | 0.87 | 0.89 | 0.91 | 0.93 | 0.95 | 0.98 | 1.00 | 1.02 | 1.04 | 1.07 | 1.098 |
| 27 | 0.85 | 0.86 | 0.88 | 0.90 | 0.92 | 0.94 | 0.96 | 0.98 | 1.01 | 1.03 | 1.05 | 1.076 |
| 30 | 0.85 | 0.86 | 0.88 | 0.89 | 0.91 | 0.93 | 0.94 | 0.96 | 1.00 | 1.02 | 1.04 | 1.059 |
| 36 | 0.84 | 0.86 | 0.87 | 0.88 | 0.90 | 0.91 | 0.92 | 0.94 | 0.97 | 1.00 | 1.01 | 1.033 |

4.13.3.3. The wheel service factor $S_m$ is equal to 1.25 times the machinery service factor $C_d$ 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 trolley load service coefficient $K_{wl} = K_{wtw} \times C_s \times S_m$ and the bridge wheel load service coefficient $K_{wl} = K_{wbw} \times C_s \times S_m$ with the following limitations:

$K_{wl}$ may not be smaller than $K_{wl}$ min. shown in Table 4.13.3-3.

4.13.3.5. The equivalent durability wheel load $P_e$ shall be determined as follows:

$$P_e = Maximum\ wheel\ load \times K_{wl}$$

The equivalent durability wheel load $P_e$ shall not exceed wheel loads $P$ listed in Table 4.13.3-4.

4.13.4. Proper Clearance for Bridge Wheels

A total of approximately ¾ inch to 1 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 or with press fit and keyed.

## TABLE 4.13.3-3

## WHEEL SERVICE FACTOR $S_m$ AND MINIMUM LOAD SERVICE FACTOR $K_{wl}$ MINIMUM

| CLASS OF CRANE SERVICE | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| $K_{wl}$ min. | 0.75 | 0.75 | 0.8 | 0.85 | 0.9 | 0.95 |
| $S_m$ | 0.8 | 0.9 | 1.0 | 1.12 | 1.25 | 1.45 |

## TABLE 4.13.3–4

## MAXIMUM PERMISSIBLE BRIDGE AND TROLLEY WHEEL LOADING $(P)$ $(lb)$

| Wheel Hardness | Whee dia. ( (in) | ASC 20# | ASCE 25# | ASCE 30# | ASCE 40# | ARA-/ 90# | ASCE 60 70# ARA-B 100# | ASCE 80 & 8 ARA-A 10 BETH 104# USS 105# | ASCE 100# | BETH USS 135# | BETH USS 175# | BETH 171# |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 200 BHN | 8 | 6750 | 8000 | 8500 | 10000 | | | | | | | |
| | 9 | 7600 | 9000 | 9550 | 11250 | 14900 | 15750 | | | | | |
| | 10 | 8450 | 10000 | 10650 | 12500 | 16550 | 17500 | | | | | |
| | 12 | | 12000 | 12750 | 15000 | 19850 | 21000 | 22500 | 25500 | | | |
| | 15 | | | 15950 | 18750 | 24850 | 26250 | 28150 | 31850 | | | |
| | 18 | | | 19150 | 22500 | 29800 | 31500 | 33750 | 38250 | 40500 | | |
| | 21 | | | | 26250 | 34800 | 36750 | 39400 | 44600 | 47250 | 65600 | 7350 |
| | 24 | | | | | 39750 | 42000 | 45000 | 51000 | 54000 | 75000 | 8400 |
| | 27 | | | | | | | 50600 | 57400 | 60750 | 84400 | 9450 |
| | 30 | | | | | | | 56250 | 63750 | 67500 | 93750 | 1050 0 |
| | 36 | | | | | | | | 76500 | 81000 | 112500 | 1260 0 |
| 260 BHN | 8 | 8800 | 10400 | 11050 | 13000 | | | | | | | |
| | 9 | 9850 | 11700 | 12450 | 14600 | 19400 | 20450 | | | | | |
| | 10 | 1095 | 13000 | 13800 | 16250 | 21550 | 22750 | | | | | |
| | 12 | | 15600 | 16600 | 19500 | 25850 | 27300 | 29250 | 33150 | | | |
| | 15 | | | 20750 | 24400 | 32300 | 34100 | 36550 | 41450 | | | |
| | 18 | | | 24850 | 29250 | 38750 | 40950 | 43850 | 49700 | 52650 | | |
| | 21 | | | | 34100 | 45200 | 47800 | 51200 | 58000 | 61400 | 85300 | 9555 |
| | 24 | | | | | 51650 | 54600 | 58500 | 66300 | 70200 | 97500 | 1092 0 |
| | 27 | | | | | | | 65800 | 74600 | 79000 | 109700 | 1228 0 |
| | 30 | | | | | | | 73100 | 82850 | 87750 | 121850 | 1365 0 |
| | 36 | | | | | | | | 99450 | 10530 | 146250 | 1638 0 |
| 320 BHN | 8 | 9400 | 11150 | 11850 | 13900 | | | | | | | |
| | 9 | 1055 | 12550 | 13300 | 15650 | 20750 | 21950 | | | | | |
| | 10 | 1175 | 13900 | 14800 | 17400 | 23050 | 24350 | | | | | |
| | 12 | | 16700 | 17750 | 20900 | 27650 | 29250 | 31300 | 35500 | | | |
| | 15 | | | 22200 | 26100 | 34600 | 36550 | 39150 | 44400 | | | |
| | 18 | | | 26650 | 31300 | 41500 | 43850 | 47000 | 53250 | 56400 | | |
| | 21 | | | | 36550 | 48400 | 51150 | 54800 | 62150 | 65800 | 91350 | 1023 0 |
| | 24 | | | | | 55350 | 58450 | 62650 | 71000 | 75200 | 104400 | 1169 0 |
| | 27 | | | | | | | 70500 | 79900 | 84550 | 117450 | 1315 0 |
| | 30 | | | | | | | 78300 | 88750 | 93950 | 130500 | 1462 0 |
| | 36 | | | | | | | | 10650 | 11275 | 156600 | 1754 0 |
| 58Rc (615 BHN | 8 | 1165 | 13800 | 14700 | 17250 | | | | | | | |
| | 9 | 1310 | 15550 | 16500 | 19450 | 25750 | 27200 | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 1460 | 17250 | 18350 | 21600 | 28600 | 30200 | | | | | |
| | 12 | | 20700 | 22050 | 25900 | 34300 | 36250 | 38850 | 44050 | | | |
| | 15 | | | 27550 | 32400 | 42900 | 45350 | 48550 | 55050 | | | |
| | 18 | | | 33050 | 38850 | 51500 | 54400 | 58300 | 66050 | 69950 | | |
| | 21 | | | | 45350 | 60050 | 63450 | 68000 | 77050 | 81600 | 113350 | 12690 |
| | 24 | | | | | 68650 | 72550 | 77700 | 88100 | 93250 | 129550 | 14500 |
| | 27 | | | | | | | 87450 | 99100 | 10490 | 145700 | 16320 |
| | 30 | | | | | | | 97150 | 11010 | 11660 | 161900 | 18130 |
| | 36 | | | | | | | | 13210 | 13990 | 194300 | 21760 |
| Effective Width Rail Head ($W$) (i (Top of head min corner radii) | | 0.844 | 1.000 | 1.063 | 1.250 | 1.656 | 1.750 | 1.875 | 2.125 | 2.250 | 3.125 | 3.500 |

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

### 4.14. BUMPERS

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.

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

4.14.1.5. 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 4.14.1.4.

4.14.1.6. 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:

- Number of cranes on runway, bridge speed, approximate weight, etc.
- Height of runway stops or bumper above the runway rail.
- Clearance between cranes and end of runway.

4.14.2. 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:

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

4.14.2.2. 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 1/3 of rated load speed.

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

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

4.14.2.5. When more than one trolley is operated on the same bridge, bumpers shall be provided on their adjacent ends or on one end of the trolley to meet the requirements of Sections 4.14.2.1 thru 4.14.2.4.

### 4.15. STOPS

4.15.1. Runway stops limiting the bridge travel are normally designed and provided by the owner or specifier.

4.15.2. Stops are located at the limits of the trolley and bridge travel and shall engage the full surface of the bumper.

4.15.3. Stops engaging the tread of the wheel are not recommended.

## 4.16. KEYS AND KEYWAYS

4.16.1. Parallel keys, tapered keys and keyways when designed to transmit torsional loads should meet the dimensional requirements of ANSI B17.1 and shall be sized in accordance with Section 4.16.3 through 4.16.6. Loads for sizing keys and keyways shall be determined consistent with shaft loads per Section 4.11.4.

4.16.2. Keys and keyways within commercially available components such as gearboxes and motors may be per the component manufacturer's standards.

4.16.3. Key Forces and Stress Formulas

| | | | |
|---|---|---|---|
| $F_{key}$ | = | $2T/D$ | Force transmitted by key |
| $\tau_{key}$ | = | $F_{key}/A_s$ | Shear stress within key |
| $\sigma_{key}$ | = | $F_{key}/A_c$ | Compressive stress on key or keyway surface |

Where:
$T$ = Torque transmitted by key
$D$ = Shaft diameter at key
$A_c$ = Effective compression area of key
$A_s$ = Shear area of key

4.16.4. Note: Keyway corner radii and key chamfers must be considered when determining compression areas of keys.

4.16.5. Allowable shear stress for Keys

4.16.6. $\tau_{ak} = \frac{\sigma_{yk}}{3\sqrt{3}}$ 4.16.7. Allowable shear stress for keys

Where: $\sigma_{yk}$ = Minimum yield strength of key

4.16.8. Allowable Compressive Stress for Keys and Keyways

4.16.8.1. Keys

4.16.9. $\sigma_{ak} = \frac{\sigma_{yk}}{3}$ 4.16.10. Allowable compressive stress for keys

Where: $\sigma_{yk}$ = Minimum yield strength of key

4.16.10.1. Shaft Keyways

4.16.11. $\sigma_{as} = \frac{\sigma_{ys}}{2}$ 4.16.12. Allowable compressive stress for shaft keyways

Where: $\sigma_{ys}$ = Minimum yield strength of shaft

4.16.12.1. Hub Keyways

4.16.13. $\sigma_{ah} = \frac{\sigma_{yh}}{2}$ 4.16.14. Allowable compressive stress for hub keyways

Where: $\sigma_{yh}$ = Minimum yield strength of hub

4.16.15. Note: The allowable compressive stresses of keys and hubs may be increased by 50% in non-reversing torque applications.

4.16.16. The allowable stresses in 4.16.4 and 4.16.5 should be reduced by applying a factor of $1.2/(1 + HLF)$ for applications with $HLF > 0.20$. Also, the allowable stresses should be reduced by an appropriate factor for travel drive applications using either DC drives or when power is applied abruptly such as reverse plugging.

***Commentary:*** *Except for the motor and brake line shaft, or when mechanical load brakes are used, shafts within the hoisting machinery are normally non-reversing torque applications. Travel motions (trolley and bridge) are always reversing torque applications.*

# 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.

5.1.2. Cranes for alternating current power supplies may be equipped with squirrel cage and/or wound rotor motors with compatible control for single speed, multispeed 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.

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

5.1.4. 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.

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

5.1.6. Electrical equipment shall comply with ASME B30.2 Safety Standard for Overhead and Gantry Cranes.

5.1.7. Refer to NEC articles 500 to 516 for additional information about wiring practices.

## 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 multispeed) types.

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

5.2.1.3. AC Motors used with Inverters:

5.2.1.3.1. Motors shall be AC Induction NEMA Design A, NEMA Design B or IEC Design N, or any other suitable motor designs selected for the particular application. Motors should be inverter duty.

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

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

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

5.2.2. Motor Insulation

5.2.3. 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°C AMBIENT, MEASURED BY RESISTANCE*+

**A.C. MOTORS**

| INSULATION CLASS | OPEN DRIP PROOF & TEFC | TENV |
|---|---|---|
| B | 80°C | 85°C |
| F | 105°C | 110°C |
| H | 125°C | 135°C |

**D.C. MOTORS**

| INSULATION CLASS | OPEN DRIP PROOF | TEFC &TENV |
|---|---|---|
| B | 100°C | 110°C |
| F | 130°C | 140°C |
| H | 155°C | 165°C |

* If ambient temperatures exceed 40°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°C ambient temperature unless otherwise specified by the purchaser.

5.2.4. Motors shall be provided with anti-friction bearings.

5.2.5. Voltage

Motor rated voltage and corresponding nominal system voltage shall be in accordance with Table 5.2.4-1 (References: AC-ANSI C84.1, Appendix and Table C3; DC-AIST Tech. Report TR-01; also NEMA MG 1-10.62)

## 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 Voltag<br>Shunt or Compound | |
| | | | | Armature | Shunt Field |
| | | 400-3-60 | 460 Max. (8) | 230 (4) | 230 (4) |
| | | 240-3-60 | (5) (8) | 240 | 150 or 240 |
| | | 460-3-60 | (6) (8) | 500 | 240 or 300 |
| | | 208 thru 600 | (8) 500 Max. | Constant Potentia<br>Series, Shunt, Compound | |
| | | | | 230 or 240 (3) (7) | |
| DC | Generator c<br>Battery | — | 250 | 230 or 240 (3) (7) | |

(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 applicable ripple is present.

(4) AIST Tech. Report TR-01-1991 (DC mill motors).

(5) NEMA MG 1–10.62.2 & Table 10-9 (industrial motors).

(6) NEMA MG 1–10.62.2 & Table 10-10 (industrial motors).

(7) Motor rated voltage may be 250 volts for large frame motors 300hp and larger.

(8) Maximum motor input voltage.

5.2.5.1. Variations—AC

5.2.5.1.1. 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 or rated motor voltage, but not necessarily at rated voltage performance values (Reference NEMA MG 1–12.45).

5.2.5.1.2. Voltage Unbalance

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

5.2.5.2. Variations—DC

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

5.2.6. 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).

5.2.7. 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.

5.2.8. Motor Time Ratings

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

## TABLE 5.2.7-1

## MINIMUM MOTOR TIME RATINGS IN MINUTES [3,4,6]

| 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 or Inverter | AC or DC Magnetic Constant Potential | AC Static with Fixed Secondary Resistance or DC Static Adj. Voltage or Inverter |
| 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 should be increased accordingly. Consult with the motor manufacturer for further information.

[5] For DC drives, appropriate service factors may be applied to the motor horsepower rating for the designated time rating. In addition to the 5.2.10.1.1.2 $K_c$ factor, to attain adequate thermal dissipating ability, with control designed accordingly.

[6] When utilizing a Continuous Duty motor because of thermal considerations in an intermittent duty application, it is not necessary to upsize the current carrying conductors for the Continuous Duty motor.

***Commentary:*** *Using, for example, a hoist motor with class F insulation and class B rise may require a continuous duty motor, even if the application is intermittent duty. The motor is chosen for the thermal rating, not for a continuous duty application.*

5.2.9. Across-the-Line starting squirrel cage motors typically 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.

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

5.2.10.1. 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.

5.2.10.1.1. Hoist Drives

5.2.10.1.1.1. Mechanical Horsepower

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

where: $LL$ = total weight in pounds to be lifted by the hoist drive rope system. This includes 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 or other supplemental devices.

$V$ = 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 = $(E_g)^n \times (E_s)^m$

$E_g$ = efficiency per gear reduction.