# TECHNICAL REFERENCE

Have a Technical question? Don't worry. Here in the c3controls Technical Reference section, you'll find all the information you need to help you make the right decision for your particular application. From enclosure ratings to hazardous location classifications to pilot duty rating codes, we've got it covered — all in a format that is easy to understand.

**Section 38**

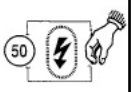
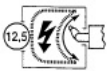
## ENCLOSURE TYPES NON-HAZARDOUS LOCATION

| Enclosure Rating | NEMA<br>National Electrical Manufacturers Association (NEMA Standard 250) and Electrical and Electronic Mfg. Association of Canada (EEMAC) | Underwriters Laboratories Inc. (UL50 and UL508) | Canadian Standards Association (Standard C22.2 No. 94) |
|---|---|---|---|
| **Type 1** | Enclosures are intended for indoor use primarily to provide a degree of protection against contact with the enclosed equipment or locations where unusual service conditions do not exist. | Indoor use primarily to provide protection against contact with the enclosed equipment and against a limited amount of falling dust. | General purpose enclosure. Protects against accidental contact with live parts. |
| **Type 3** | Enclosures are intended for outdoor use primarily to provide a degree of protection against windblown dust, rain, and sleet; undamaged by the formation of ice on the enclosure. | Outdoor use to provide a degree of protection against windblown dust and windblown rain; undamaged by the formation of ice on the enclosure. | Indoor or outdoor use; provides a degree of protection against rain, snow, and windblown dust; undamaged by the external formation of ice on the enclosure. |
| **Type 3R*** | Enclosures are intended for outdoor use primarily to provide a degree of protection against falling rain and sleet; undamaged by the formation of ice on the enclosure. | Outdoor use to provide a degree of protection against falling rain; undamaged by the formation of ice on the enclosure. | Indoor or outdoor use; provides a degree of protection against rain and snow; undamaged by the external formation of ice on the enclosure. |
| **Type 4** | Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water, and hose directed water; undamaged by the formation of ice on the enclosure. | Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure. | Indoor or outdoor use; provides a degree of protection against rain, snow, windblown dust, splashing and hose-directed water; undamaged by the external formation of ice on the enclosure. |
| **Type 4X** | Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure. | Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure; resists corrosion. | Indoor or outdoor use; provides a degree of protection against rain, snow, windblown dust, splashing and hose-directed water; undamaged by the external formation of ice on the enclosure; resists corrosion. |
| **Type 6** | Enclosures are intended for use indoors or outdoors where occasional submersion is encountered, limited depth, undamaged by the formation of ice on the enclosure. | Indoor or outdoor use to provide a degree of protection against entry of water during temporary submersion at a limited depth; undamaged by the external formation of ice on the enclosure. | Indoor or outdoor use; provides a degree of protection against the entry of water during temporary submersion at a limited depth. Undamaged by the external formation of ice on the enclosure; resists corrosion. |
| **Type 12** | Enclosures are intended for indoor use primarily to provide a degree of protection against dust, falling dirt, and dripping non-corrosive liquids. | Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water, and external condensation of non-corrosive liquids. | Indoor use; provides a degree of protection against circulating dust, lint, fibers, and flyings; dripping and light splashing of non-corrosive liquids; not provided with knockouts. |
| **Type 12K** | Enclosures with knockouts are intended for indoor use primarily to provide a degree of protection against dust, falling dirt, and dropping non-corrosive liquids. | Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water, and external condensation of non-corrosive liquids. Knockouts located in the top or bottom walls, or both. | Indoor use; provides a degree of protection against circulating dust, lint, fibers and flyings; dripping and light splashing of non-corrosive liquids; provided with knockouts. |
| **Type 13** | Enclosures are intended for indoor use primarily to provide a degree of protection against dust, spraying of water, oil, and non-corrosive coolant. | Indoor use to provide a degree of protection against lint, dust seepage, external condensation and spraying of water, oil, and non-corrosive liquids. | Indoor use; provides a degree of protection against circulating dust, lint, fibers, and flyings; seepage and spraying of non-corrosive liquids, including oils and coolants. |

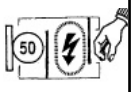
***NFPA 70 (National Electric Code) defines new Type 3RX as providing the same degree of protection as Type 3R, with the addition of protection against corrosive agents.**

Source: NEMA, UL and CSA Standards.

## FIRST NUMERAL

| Protection Against Ingress of Solid Objects | | | Protection of Persons Against Access to Hazardous Parts with: |
|---|---|---|---|
| **IP** | **Requirements** | **Example** | |
| 0 | No protection. |  | Non-Protected |
| 1 | Full penetration of 50mm diameter sphere not allowed. Contact with hazardous parts not permitted. |  | Back of Hand |
| 2 | Full penetration of 12.5mm diameter sphere not allowed. The jointed test finger shall have adequate clearance from hazardous parts. |  | Finger |
| 3 | The access probe of 2.5mm diameter shall not penetrate. |  | Tool |
| 4 | The access probe of 1.0mm diameter shall not penetrate. |  | Wire |
| 5 | Limited ingress of dust permitted (no harmful deposit). |  | Wire |
| 6 | Totally protected against ingress of dust. |  | Wire |

## ADDITIONAL LETTER (OPTIONAL)

| Protection Against Ingress of Solid Objects | | | Protection of Persons Against Access to Hazardous Parts with: |
|---|---|---|---|
| **IP** | **Requirements** | **Example** | |
| A (For use with first numeral 0) | Penetration of 50mm diameter sphere up to barrier must not contact hazardous parts. |  | Back of Hand |
| B (For use with first numerals 0 and 1) | Test finger penetration to a maximum of 80mm must not contact hazardous parts. |  | Finger |
| C (For use with first numerals 1 and 2) | Wire of 2.5mm diameter x 10mm long must not contact hazardous parts when spherical stop face is partially entered. |  | Tool |
| D (For use with first numerals 2 and 3) | Wire of 1.0mm diameter x 100mm long must not contact hazardous parts when spherical stop face is partially entered. |  | Wire |

## SECOND NUMERAL

| Protection Against Harmful Ingress of Water | | | Protection from Water: |
|---|---|---|---|
| **IP** | **Requirements** | **Example** | |
| 0 | No protection. |  | Non-Protected |
| 1 | Protected against vertically falling drops of water. Limited ingress permitted. |  | Vertically Dripping |
| 2 | Protected against vertically falling drops of water with enclosure tilted 15° from the vertical. Limited ingress permitted. |  | Dripping up to 15° from the Vertical |
| 3 | Protected against sprays to 60° from the vertical. Limited ingress permitted. |  | Limited Spraying |
| 4 | Protected against water splashed from all directions. Limited ingress permitted. |  | Splashing from all Directions |
| 5 | Protected against jets of water. Limited ingress permitted. |  | Hosing Jets from all Directions |
| 6 | Protected against strong jets of water. Limited ingress permitted. |  | Strong Hosing Jets from all Directions |
| 7 | Protected against the effects of immersion between 15cm and 1m. |  | Temporary Immersion |
| 8 | Protected against long periods of immersion under pressure. |  | Continuous Immersion |

Source: ©International Electrotechnical Commission

## NEMA ENCLOSURE TYPE RATINGS / IEC ENCLOSURE IP RATINGS

### CONVERSION OF NEMA ENCLOSURE TYPE RATINGS TO IEC 60529 ENCLOSURE CLASSIFICATION DESIGNATIONS (IP) (CANNOT BE USED TO CONVERT IEC CLASSIFICATION DESIGNATIONS TO NEMA TYPE RATINGS)

| IP FIRST CHARACTER | NEMA ENCLOSURE TYPE | | | | | | | | | | | | | | | | | | | | | | | | | | IP SECOND CHARACTER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 3R | | 3S | | 4 | | 4X | | 5 | | 6 | | 6P | | 12 | | 12K | | 13 | | |
| IP0_ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | IP_0 |
| IP1_ | | | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | IP_1 |
| IP2_ | | | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | IP_2 |
| IP3_ | | | | | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | | ■ | IP_3 |
| IP4_ | | | | | | ■ | | ■ | | ■ | | ■ | | ■ | | | | ■ | | ■ | | ■ | | ■ | | ■ | IP_4 |
| IP5_ | | | | | | ■ | | | | ■ | | ■ | | ■ | | | | ■ | | ■ | | | | | | ■ | IP_5 |
| IP6_ | | | | | | | | | | | | ■ | | ■ | | | | ■ | | ■ | | | | | | | IP_6 |
| | | | | | | | | | | | | | | | | | | | ■ | ■ | | | | | | | IP_7 |
| | | | | | | | | | | | | | | | | | | | | ■ | | | | | | | IP_8 |
| | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B | |

**A =** **A shaded block in the "A" column indicates that the NEMA Enclosure Type exceeds the requirements for the respective IEC 60529 IP First Character Designation. The IP First Character Designation is the protection against access to hazardous parts and solid foreign objects.**

**B =** **A shaded block in the "B" column indicates that the NEMA Enclosure Type exceeds the requirements for the respective IEC 60529 IP Second Character Designation. The IP Second Character Designation is the protection against the ingress of water.**

**Examples of Table Use:**
An IEC IP45 Enclosure Rating is specified. What NEMA Type Enclosures meet and exceed the IP45 rating?

Referencing the first character, 4, in the IP rating and the row designated "IP4_" in the leftmost column in the table; the blocks in Column "A" for NEMA Types 3, 3S, 4, 4X, 5, 6, 6P, 12, 12K and 13 are shaded. These NEMA ratings meet and exceed the IEC protection requirements against access to hazardous parts and solid foreign objects. Referencing the second character, 5, in the IP rating and the row designated "IP_5" in the rightmost column in the table; the blocks in Column "B" for NEMA Type 3, 3S, 4, 4X, 6 and 6P are shaded. These NEMA ratings meet and exceed the IEC requirements for protection against the ingress of water. The absence of shading in Column "B" beneath the "NEMA Enclosure Type 5" indicates that Type 5 does not meet the IP45 protection requirements against the ingress of water. Likewise, the absence of shading Column "B" for NEMA Type 12, 12K and 13 enclosures indicates that these enclosures do not meet the IP45 requirements for protection against the ingress of water. Only Type 3, 3S, 4, 4X, 6 and 6P have both Column "A" in the "IP4_" row and Column "B" in the "IP_5" row shaded and could be used in an IP45 application.

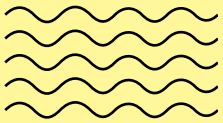
The NEMA Enclosure Type 3 not only meets the IP45 Enclosure Rating, but also exceeds the IEC requirements because the NEMA Type requires an outdoor corrosion test; a gasket aging test; a dust test; an external icing test; and no water penetration in the rain test. Slight differences exist between the IEC and NEMA test methods, but the IEC rating permits the penetration of water if "it does not deposit on insulation parts, or reach live parts." The IEC rating does not require a corrosion test; gasket aging test; dust test or external icing test. Because the NEMA ratings include additional test requirements, this table cannot be used to select IP Designations for NEMA rated enclosure specifications.

IEC 60529 specifies that an enclosure shall only be designated with a stated degree of protection indicated by the first characteristic numeral if it also complies with all lower degrees of protection. Furthermore, IEC 60529 states that an enclosure shall only be designated with a degree of protection indicated by the second characteristic numeral if it also complies with all lower degrees of protection up to and including the second characteristic numeral 6. An enclosure designated with a second characteristic numeral 7 or 8 only is considered unsuitable for exposure to water jets (designated by second characteristic numeral 5 or 6) and need not comply with requirements for numeral 5 or 6 unless it is dual coded. Since the IEC protection requirements become more stringent with increasing IP character value up through 6, once a NEMA Type rating meets the requirements for an IP designation up through 6, it will also meet the requirements for all lower IP designations. This is apparent from the shaded areas shown in the table.



## HAZARDOUS LOCATION CLASSIFICATIONS

### SUMMARY OF CLASSIFICATION CHART

| CLASS | DIVISION | GROUP |
|---|---|---|
| I. Gas  | 1. **Hazard May Exist** May exist in atmosphere under normal operating conditions. | A. Acetylene<br>B. Hydrogen and Manufactured Gases Containing Hydrogen<br>C. Petrochemicals (e.g. Ethylene)<br>D. Petrochemicals (e.g. Alcohol) |
| | 2. **Potential Hazard**<br>A. May be present in atmosphere only under abnormal circumstances.<br>B. Location adjacent to Division 1 location. | A. Acetylene<br>B. Hydrogen and Manufactured Gases Containing Hydrogen<br>C. Petrochemicals (e.g. Ethylene)<br>D. Petrochemicals (e.g. Alcohol) |
| II. Dust  | 1. **Hazard May Exist** May exist in atmosphere under normal operating conditions. | E. Conductive and Combustible Dust (e.g., Aluminum, Magnesium)<br>F. Carbonaceous Dust (e.g., Coal)<br>G. Non-Conductive Combustible Dust (e.g., plastic, chemical, food, grain) |
| | 2. **Potential Hazard**<br>A. May be present in atmosphere only under abnormal circumstances. | |
| III. Fibers  | 1. **Production Areas** | Easily Ignitable Fibers or Flyings |
| | 2. **Handling and Storage Areas** | Easily Ignitable Fibers or Flyings |

## PUSH BUTTON COLORS

| COLOR-CODING FOR PUSH BUTTON ACTUATORS AND THEIR MEANINGS | | | |
|---|---|---|---|
| **COLOR** | **MEANING** | **EXPLANATION** | **EXAMPLES OF APPLICATION** |
| RED | Emergency | Actuate in the event of a hazardous condition or emergency | Emergency Stop<br>Initiation of emergency function |
| YELLOW | Abnormal | Actuate in the event of an abnormal condition | Intervention to suppress abnormal condition<br>Intervention to restart an interrupted automatic cycle |
| GREEN | Normal | Actuate to initiate normal conditions | (See following table) |
| BLUE | Mandatory | Actuate for a condition requiring mandatory action | Reset function |
| WHITE | No specific meaning assigned | For general initiation of functions except for emergency stop (see note) | START/ON (preferred)<br>STOP/OFF |
| GREY | | | START/ON<br>STOP/OFF |
| BLACK | | | START/ON<br>STOP/OFF (preferred) |

NOTE: Where a supplemental means of coding (e.g. shape, position, texture) is used for the identification of push button actuators, then the same color WHITE, GREY, or BLACK may be used for various functions (e.g. WHITE for START/ON and for STOP/OFF actuators).

| COLORS OF TYPICAL PUSH BUTTON OPERATORS, BY FUNCTION | | | | | |
|---|---|---|---|---|---|
| **ACTUATOR FUNCTION** | **SHALL BE USED** | **SHOULD BE USED** | **PREFERRED COLOR** | **PERMITTED COLOR** | **SHALL NOT BE USED** |
| START/ON | — | White, Grey, or Black | White | Green | Red |
| Emergency Stop and Emergency Switching OFF | Red | — | — | — | — |
| STOP/OFF | — | Black, Grey, or White | Black | Red | Green |
| Push Button Actuators that alternately act as START/ON and STOP/OFF | — | — | White, Grey, or Black | — | Red, Yellow, or Green |
| Push Button Actuators that cause operation while they are actuated and cease the operation when they are released (ex. Hold-to-Run) | — | — | White, Grey, or Black | — | Red, Yellow, or Green |
| Reset Push Buttons | Blue, White, Grey, or Black | — | — | — | Green |
| Reset Push Buttons that also act as a STOP/OFF button | — | Blue, White, Grey, or Black | Black | — | Green |

Source: IEC 60204-1, Safety of Machinery, Electrical Equipment of Machines, Part 1 General Rules

## PUSH BUTTON COLORS

**COLORS OF TYPICAL PUSH BUTTON OPERATORS, BY FUNCTION**

| ACTUATOR FUNCTION | SHALL BE USED | SHOULD BE USED | PREFERRED COLOR | PERMITTED COLOR | SHALL NOT BE USED |
|---|---|---|---|---|---|
| START/ON | — | — | Green | White, Grey, or Black | Red |
| Emergency Stop | Red | — | — | — | — |
| STOP/OFF | — | — | Red | White, Grey, or Black | Green |
| Push Button Actuators that alternately act as START/ON and STOP/OFF | White, Grey, or Black | — | — | — | Red, Yellow, or Green |
| Push Buttons used to respond to abnormal conditions | Yellow | — | — | — | — |
| Push Button Actuators that cause operation while they are actuated and cease the operation when they are released (ex. Jogging) | White, Grey, Blue, or Black | — | Black | — | — |
| Reset Push Buttons | Blue, White, Grey, or Black | — | — | — | Green |
| Reset Push Buttons that also act as a STOP/OFF button | Red | — | — | — | — |

Source: NFPA 79 Electrical Standard for Industrial Machinery

## INDICATOR LIGHT COLORS

Indicator lights and displays serve to give the following types of information:

- Indication – to attract the operator's attention or to indicate that a certain task should be performed. The colors RED, YELLOW, GREEN, and BLUE are normally used in this mode.
- Confirmation – to confirm a command, or a condition, or to confirm the termination of a change or transition period. The colors BLUE and WHITE are normally used in the mode and GREEN may be used in some cases.
- Unless otherwise agreed to between the supplier and user, indicator (pilot) light lenses shall be color-coded with respect to the condition (status) of the machine in accordance with the following table.

**COLORS FOR INDICATOR LIGHTS AND THEIR MEANINGS WITH RESPECT TO THE CONDITION OF THE MACHINE**

| COLOR | MEANING | EXPLANATION | ACTION BY OPERATOR |
|---|---|---|---|
| RED | Emergency | Hazardous condition | Immediate action to deal with hazardous condition (e.g. by operating emergency stop) |
| YELLOW | Abnormal | Abnormal condition<br>Impending critical condition | Monitoring and/or intervention (e.g. by re-establishing the intended function) |
| GREEN | Normal | Normal condition | Optional |
| BLUE | Mandatory | Indication of a condition that requires action by the operator | Mandatory action |
| WHITE | Neutral | Other conditions; may be used whenever doubt exists about the application of RED, YELLOW, GREEN, BLUE | Monitoring |

NOTE: Alternative meanings to those defined in the preceding table may be assigned in accordance with one of the following criteria: the safety of persons and the environment, and the state of the electrical equipment.

Source: ©International Electrotechnical Commission

## INDICATOR LIGHTS

**MACHINE INDICATOR LIGHTS**

| COLOR | SAFETY OF PERSONS OR ENVIRONMENT | CONDITION OF PROCESS | STATE OF EQUIPMENT |
|---|---|---|---|
| RED | Danger | Emergency | Faulty |
| YELLOW (AMBER) | Warning/Caution | Abnormal | Abnormal |
| GREEN | Safe | Normal | Normal |
| BLUE | Mandatory Action | Mandatory Action | Mandatory Action |
| CLEAR<br>WHITE<br>GREY<br>BLACK | No specific meaning assigned | No specific meaning assigned | No specific meaning assigned |

Source: NFPA 79 Electrical Standard for Industrial Machinery

## CONDUCTOR COLORS

**IEC 60204-1: COLORS OF CONDUCTORS, BY CONDUCTOR TYPE**

| CONDUCTOR TYPE | COLOR SHALL BE USED | RECOMMENDED COLOR |
|---|---|---|
| Ground/Earth | GREEN and YELLOW | — |
| Neutral | LIGHT BLUE | — |
| AC and DC Power Circuits | — | BLACK |
| AC Control Circuits | — | RED |
| DC Control Circuits | — | BLUE |
| Interlock Control Circuits Supplied from an External Power Source | — | ORANGE |

NOTE: Where color-coding is used for the identification of conductors, the following colors may be used: BLACK, BROWN, RED, ORANGE, YELLOW, GREEN, BLUE (including LIGHT BLUE), VIOLET, GREY, WHITE, PINK, and TURQUOISE.

Source: IEC 60204-1, Safety of Machinery, Electrical Equipment of Machines, Part 1 General Rules

**NFPA 79: COLORS OF CONDUCTORS, BY CONDUCTOR TYPE**

| CONDUCTOR TYPE | COLOR |
|---|---|
| Ground (protective bonding)/Earth | GREEN with or without one or more YELLOW stripes |
| AC Circuit with a grounded conductor | WHITE, GREY or three continuous WHITE stripes on other than GREEN, BLUE, ORANGE, or YELLOW insulation |
| Grounded DC circuit conductor (current carrying) | WHITE with BLUE stripe |
| Grounded (current carrying) circuit conductor which remains energized when the main disconnecting means is in the OFF position | WHITE with ORANGE stripe or WHITE with YELLOW stripe |
| Ungrounded circuit conductors that remain energized when the supply disconnecting means is in the OFF position | ORANGE or YELLOW |
| Ungrounded line, load, and control conductors at line voltage | BLACK |
| Ungrounded AC control conductors at less than line voltage | RED |
| Ungrounded DC control conductors | BLUE |

Source: NFPA 79 Electrical Standard for Industrial Machinery

# PILOT DUTY RATING CODES

## RATING CODES FOR AC CONTROL-CIRCUIT CONTACTS AT 50 AND 60 HERTZ

| CONTACT RATING CODE DESIGNATION[a] | THERMAL CONTINUOUS TEST CURRENT AMPERES | MAXIMUM CURRENT, AMPERES[b] | | | | | | | | MAXIMUM VOLT-AMPERES | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 120 VOLT | | 240 VOLT | | 480 VOLT | | 600 VOLT | | | |
| | | MAKE | BREAK | MAKE | BREAK | MAKE | BREAK | MAKE | BREAK | MAKE | BREAK |
| A150 | 10 | 60 | 6.00 | – | – | – | – | – | – | 7200 | 720 |
| A300 | 10 | 60 | 6.00 | 30 | 3.00 | – | – | – | – | 7200 | 720 |
| A600 | 10 | 60 | 6.00 | 30 | 3.00 | 15 | 1.50 | 12 | 1.20 | 7200 | 720 |
| | | | | | | | | | | | |
| B150 | 5 | 30 | 3.00 | – | – | – | – | – | – | 3600 | 360 |
| B300 | 5 | 30 | 3.00 | 15 | 1.50 | – | – | – | – | 3600 | 360 |
| B600 | 5 | 30 | 3.00 | 15 | 1.50 | 7.50 | 0.75 | 6 | 0.60 | 3600 | 360 |
| | | | | | | | | | | | |
| C150 | 2.5 | 15 | 1.5 | – | – | – | – | – | – | 1800 | 180 |
| C300 | 2.5 | 15 | 1.5 | 7.5 | 0.75 | – | – | – | – | 1800 | 180 |
| C600 | 2.5 | 15 | 1.5 | 7.5 | 0.75 | 3.75 | 0.375 | 3.00 | 0.30 | 1800 | 180 |
| | | | | | | | | | | | |
| D150 | 1.0 | 3.60 | 0.60 | – | – | – | – | – | – | 4.32 | 72 |
| D300 | 1.0 | 3.60 | 0.60 | 1.80 | 0.30 | – | – | – | – | 4.32 | 72 |
| | | | | | | | | | | | |
| E150 | 0.5 | 1.80 | 0.30 | – | – | – | – | – | – | 216 | 36 |

[a] The numerical suffix designates the maximum voltage design values, which are to be 600, 300, and 150 volts for suffixes 600, 300, and 150, respectively. The test voltage is to be 600, 240, or 120 volts.

[b] For maximum ratings at voltages between the maximum design value and 120 volts, the maximum make and break ratings are to be obtained by dividing the volt-amperes rating by the application voltage. For voltages below 120 volts, the maximum make current is to be the same as for 120 volts, and the maximum break current is to be obtained by dividing the break volt-amperes by the application voltage, but these currents are not to exceed the thermal continuous test current.

## RATING CODES FOR DC CONTROL-CIRCUIT CONTACTS

| CONTACT RATING CODE DESIGNATION[a] | THERMAL CONTINUOUS TEST CURRENT AMPERES | MAXIMUM MAKE OR BREAK[b] CURRENT, AMPERES | | | MAXIMUM MAKE OR BREAK VOLT-AMPERES AT 300 VOLTS OR LESS |
|---|---|---|---|---|---|
| | | 125 VOLT | 250 VOLT | 301 TO 600 VOLT | |
| N150 | 10 | 2.2 | – | – | 275 |
| N300 | 10 | 2.2 | 1.1 | – | 275 |
| N600 | 10 | 2.2 | 1.1 | 0.40 | 275 |
| | | | | | |
| P150 | 5.0 | 1.1 | – | – | 138 |
| P300 | 5.0 | 1.1 | 0.55 | – | 138 |
| P600 | 5.0 | 1.1 | 0.55 | 0.20 | 138 |
| | | | | | |
| Q150 | 2.5 | 0.55 | – | – | 69 |
| Q300 | 2.5 | 0.55 | 0.27 | – | 69 |
| Q600 | 2.5 | 0.55 | 0.27 | 0.10 | 69 |
| | | | | | |
| R150 | 1.0 | 0.22 | – | – | 28 |
| R300 | 1.0 | 0.22 | 0.11 | – | 28 |

[a] The numerical suffix designates the maximum voltage design values, which are to be 600, 300, and 150 volts for suffixes 600, 300, and 150, respectively. The test voltage is to be 600, 250, or 125 volts.

[b] For maximum ratings at 300 volts or less, the maximum make and break ratings are to be obtained by dividing the volt-ampere rating by the application voltage, but the current values are not to exceed the thermal continuous test current.

Source: Extracts from ©UL508 – Industrial Control Equipment, Seventeenth Edition

## IEC UTILIZATION CATEGORIES

### LOW VOLTAGE UTILIZATION CATEGORIES

| NATURE OF CURRENT | CATEGORY | TYPICAL APPLICATIONS | RELEVANT IEC PRODUCT STANDARD |
|---|---|---|---|
| a.c. | AC-1 | Non-inductive or slightly inductive loads, resistance furnaces. | 60947-4 |
| | AC-2 | Slip-ring motors: starting, switching off. | |
| | AC-3 | Squirrel-cage motors: starting, switching off motors during running. | |
| | AC-4 | Squirrel-cage motors: starting, plugging[1], inching[2]. | |
| | AC-5a | Switching of electric discharge lamp control. | |
| | AC-5b | Switching of incandescent lamps. | |
| | AC-6a | Switching of transformers. | |
| | AC-6b | Switching of capacitor banks. | |
| | AC-7a | Slightly inductive loads in household appliances and similar applications. | |
| | AC-7b | Motor-loads for household applications. | |
| | AC-8a | Hermetic refrigerant compressor motor control with manual resetting of overload releases. | |
| | AC-8b | Hermetic refrigerant compressor motor control with automatic resetting of overload releases. | |
| | AC-12 | Control of resistive loads and solid-state loads with isolation by optocoupler. | 60947-5 |
| | AC-13 | Control of solid-state loads with transformer isolation. | |
| | AC-14 | Control of small electromagnetic loads. | |
| | AC-15 | Control of a.c. electromagnetic loads. | |
| | AC-20 | Connecting and disconnecting under no-load conditions. | 60947-3 |
| | AC-21 | Switching of resistive loads, including moderate overloads. | |
| | AC-22 | Switching of mixed resistive and inductive loads, including moderate overloads. | |
| | AC-23 | Switching of motor loads or other highly inductive loads. | |
| a.c. and d.c. | A | Protection of circuits, with no rated short-time withstand current. | 60947-2 |
| | B | Protection of circuits, with a rated short-time withstand current. | |
| d.c. | DC-1 | Non-inductive or slightly inductive loads, resistance furnaces. | 60947-4 |
| | DC-3 | Shunt-motors, starting, plugging[1], inching[2], dynamic breaking of motors. | |
| | DC-5 | Series-motors, starting, plugging[1], inching[2], dynamic breaking of motors. | |
| | DC-6 | Switching of incandescent lamps. | |
| | DC-12 | Control of resistive loads and solid-state loads with isolation by optocouplers. | 60947-5 |
| | DC-13 | Control of d.c. electromagnets. | |
| | DC-14 | Control of d.c. electromagnetic loads having economy resistors in circuit. | |
| | DC-20 | Connecting and disconnecting under no-load conditions. | 60947-3 |
| | DC-21 | Switching of resistive loads, including moderate overloads. | |
| | DC-22 | Switching of mixed resistive and inductive loads, including moderate overloads, (e.g. shunt motors). | |
| | DC-23 | Switching of highly inductive loads, (e.g. series motors). | |

[1] By plugging is understood stopping or reversing the motor rapidly by reversing motor primary connections while the motor is running.

[2] By inching (jogging) is understood energizing a motor once or repeatedly for short periods to obtain small movements of the driven mechanism.

Source: ©International Electrotechnical Commission

## FULL-LOAD CURRENT, THREE-PHASE ALTERNATING-CURRENT MOTORS

### THREE-PHASE ALTERNATING-CURRENT MOTORS

| | INDUCTION-TYPE SQUIRREL CAGE AND WOUND ROTOR (AMPERES) | | | | | | | SYNCHRONOUS-TYPE UNITY POWER FACTOR* (AMPERES) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HORSEPOWER | 115 VOLTS | 200 VOLTS | 208 VOLTS | 230 VOLTS | 460 VOLTS | 575 VOLTS | 2300 VOLTS | 230 VOLTS | 460 VOLTS | 575 VOLTS | 2300 VOLTS |
| 1/2 | 4.4 | 2.5 | 2.4 | 2.2 | 1.1 | 0.9 | — | — | — | — | — |
| 3/4 | 6.4 | 3.7 | 3.5 | 3.2 | 1.6 | 1.3 | — | — | — | — | — |
| 1 | 8.4 | 4.8 | 4.6 | 4.2 | 2.1 | 1.7 | — | — | — | — | — |
| 1-1/2 | 12.0 | 6.9 | 6.6 | 6.0 | 3.0 | 2.4 | — | — | — | — | — |
| 2 | 13.6 | 7.8 | 7.5 | 6.8 | 3.4 | 2.7 | — | — | — | — | — |
| 3 | — | 11.0 | 10.6 | 9.6 | 4.8 | 3.9 | — | — | — | — | — |
| 5 | — | 17.5 | 16.7 | 15.2 | 7.6 | 6.1 | — | — | — | — | — |
| 7-1/2 | — | 25.3 | 24.2 | 22 | 11 | 9 | — | — | — | — | — |
| 10 | — | 32.2 | 30.8 | 28 | 14 | 11 | — | — | — | — | — |
| 15 | — | 48.3 | 46.2 | 42 | 21 | 17 | — | — | — | — | — |
| 20 | — | 62.1 | 59.4 | 54 | 27 | 22 | — | — | — | — | — |
| 25 | — | 78.2 | 74.8 | 68 | 34 | 27 | — | 53 | 26 | 21 | — |
| 30 | — | 92 | 88 | 80 | 40 | 32 | — | 63 | 32 | 26 | — |
| 40 | — | 120 | 114 | 104 | 52 | 41 | — | 83 | 41 | 33 | — |
| 50 | — | 150 | 143 | 130 | 65 | 52 | — | 104 | 52 | 42 | — |
| 60 | — | 177 | 169 | 154 | 77 | 62 | 16 | 123 | 61 | 49 | 12 |
| 75 | — | 221 | 211 | 192 | 96 | 77 | 20 | 155 | 78 | 62 | 15 |
| 100 | — | 285 | 273 | 248 | 124 | 99 | 26 | 202 | 101 | 81 | 20 |
| 125 | — | 359 | 343 | 312 | 156 | 125 | 31 | 253 | 126 | 101 | 25 |
| 150 | — | 414 | 396 | 360 | 180 | 144 | 37 | 302 | 151 | 121 | 30 |
| 200 | — | 552 | 528 | 480 | 240 | 192 | 49 | 400 | 201 | 161 | 40 |
| 250 | — | — | — | — | 302 | 242 | 60 | — | — | — | — |
| 300 | — | — | — | — | 361 | 289 | 72 | — | — | — | — |
| 350 | — | — | — | — | 414 | 336 | 83 | — | — | — | — |
| 400 | — | — | — | — | 477 | 382 | 95 | — | — | — | — |
| 450 | — | — | — | — | 515 | 412 | 103 | — | — | — | — |
| 500 | — | — | — | — | 590 | 472 | 118 | — | — | — | — |

*NOTE: For 90 and 80 percent power factor, the figures shall be multiplied by 1.1 and 1.25, respectively.

Source: National Electrical Code, Article 430 – Motors, Motor Circuits, and Controllers

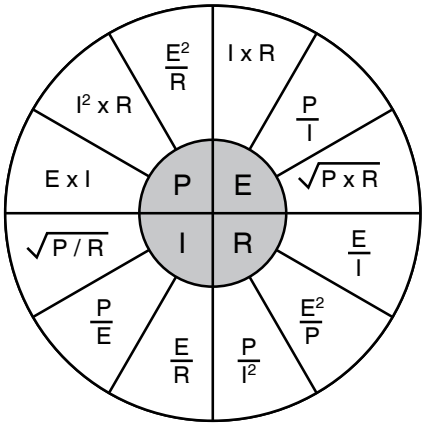
## FULL-LOAD CURRENTS IN AMPERES

### SINGLE-PHASE ALTERNATING-CURRENT MOTORS

| HORSEPOWER | 115 VOLTS | 200 VOLTS | 208 VOLTS | 230 VOLTS |
|---|---|---|---|---|
| 1/6 | 4.4 | 2.5 | 2.4 | 2.2 |
| 1/4 | 5.8 | 3.3 | 3.2 | 2.9 |
| 1/3 | 7.2 | 4.1 | 4.0 | 3.6 |
| 1/2 | 9.8 | 5.6 | 5.4 | 4.9 |
| 3/4 | 13.8 | 7.9 | 7.6 | 6.9 |
| 1 | 16 | 9.2 | 8.8 | 8.0 |
| 1-1/2 | 20 | 11.5 | 11.0 | 10 |
| 2 | 24 | 13.8 | 13.2 | 12 |
| 3 | 34 | 19.6 | 18.7 | 17 |
| 5 | 56 | 32.2 | 30.8 | 28 |
| 7-1/2 | 80 | 46.0 | 44.0 | 40 |
| 10 | 100 | 57.5 | 55.0 | 50 |

Source: National Electrical Code, Article 430 – Motors, Motor Circuits, and Controllers

## OHM'S LAW




## AC/DC FORMULAS

| TO FIND | DIRECT CURRENT | AC 1-PHASE | AC 3-PHASE |
|---|---|---|---|
| Amps when Horsepower is known | $\frac{HP \times 746}{E \times Eff}$ | $\frac{HP \times 746}{E \times Eff \times PF}$ | $\frac{HP \times 746}{1.73 \times E \times Eff \times PF}$ |
| Amps when Kilowatts is known | $\frac{kW \times 1000}{E}$ | $\frac{kW \times 1000}{E \times PF}$ | $\frac{kW \times 1000}{1.73 \times E \times PF}$ |
| Amps when kVA is known | – – | $\frac{kVA \times 1000}{E}$ | $\frac{kVA \times 1000}{1.73 \times E}$ |
| Kilowatts | $\frac{I \times E}{1000}$ | $\frac{I \times E \times PF}{1000}$ | $\frac{I \times E \times 1.73 \times PF}{1000}$ |
| Kilovolt-Amps | – – | $\frac{I \times E}{1000}$ | $\frac{I \times E \times 1.73}{1000}$ |
| Horsepower (output) | $\frac{I \times E \times Eff}{746}$ | $\frac{I \times E \times Eff \times PF}{746}$ | $\frac{I \times E \times Eff \times 1.73 \times PF}{746}$ |

**ABBREVIATIONS:**
E = Volts, I = Amps, W = Watts, PF = Power Factor, Eff = Efficiency, HP = Horsepower

## AC EFFICIENCY AND POWER FACTOR FORMULAS

| TO FIND | SINGLE PHASE | THREE PHASE |
|---|---|---|
| Efficiency | $\frac{746 \times HP}{E \times I \times PF}$ | $\frac{746 \times HP}{E \times I \times PF \times 1.732}$ |
| Power Factor | $\frac{Input\ Watts}{E \times I}$ | $\frac{Input\ Watts}{E \times I \times PF \times 1.732}$ |

**ABBREVIATIONS:**
E = Volts, I = Amps, PF = Power Factor, HP = Horsepower

## METRIC CONVERSION FACTORS

| FROM | TO | MULTIPLY BY |
|---|---|---|
| ***LENGTH*** | | |
| Inches (in.) | Millimeters (mm) | 25.4 |
| Inches (in.) | Centimeters (cm) | 2.54 |
| Feet (ft.) | Meters (m) | 0.305 |
| Yards (yd.) | Meters (m) | 0.914 |
| ***WEIGHT*** | | |
| Ounces (oz.) | Grams (g) | 28.3 |
| Pounds (lb.) | Kilograms (kg) | 0.454 |
| Grams (g) | Ounces (oz.) | 0.0353 |
| Kilograms (kg) | Pounds (lb.) | 2.20 |
| ***TORQUE*** | | |
| Pound inch (lb-in.) | Newton meters (Nm) | 0.113 |
| Newton meters (Nm) | Pound inch (lb-in.) | 8.85 |
| ***TEMPERATURE*** | | |
| Degrees Fahrenheit (°F) | Degrees Celsius (°C)* | |
| Degrees Celsius (°C) | Degrees Fahrenheit (°F)† | |

*Conversion Formula: 5/9 (°F - 32° F) = °C
†Conversion Formula: 9/5 (°C) + 32° F = °F

## ANSI AND IEC ELECTRICAL SYMBOLS, CODES AND DESCRIPTIONS

| ANSI SYMBOL | ANSI CODE | IEC 61346-2 SYMBOL | IEC CODE | DESCRIPTION |
|---|---|---|---|---|
| | CON | | KM | Contactor Contact Open |
| | CON | | KM | Contactor Contact Closed |
| | CR | | KA | Relay Contact Open |
| | CR | | KA | Relay Contact Closed |
| | TR | | KT | Timed Contact, NO - On Delay (TDE) |
| | TR | | KT | Timed Contact, NC - On Delay (TDE) |
| | TR | | KT | Timed Contact, NC - Off Delay (TDD) |
| | TR | | KT | Timed Contact, NO - Off Delay (TDD) |
| | SS | | SA | Selector Switch |
| | PB | | SB | Push Button NO |
| | PB | | SB | Push Button NC |
| | PB | | SB | Push Button Mushroom Head |
| | FL | | SL | Liquid Level Switch |
| | FLS | F | SF | Flow Switch |
| | PS | P | SP | Pressure Switch |
| | TS | | ST | Temperature Switch |
| | LS | | SQ | Limit Switch |
| | PRS | | SQ | Proximity Switch |
| A | LT | A | HL | Indicating Light |
| | PL | | XS | Plug and Socket |
| CR | CR | | KA | Control Relay Coil |
| C1 | CON | | KM | Contactor Coil |
| M1 | M | | KM | Motor Starter Coil |
| TR | TR | | KA | Timer Coil |
| | SOL | | YV | Solenoid Coil |
| | CTR | | EC | Electromechanical Counter |
| | CB | | QF | Circuit Breaker |
| | T1 | | X1<br>XT | Terminals (reference)<br>Fused Terminals (reference) |
| | FU | | FU | Fuse, Protective |

Source: NFPA 79 Electrical Standard for Industrial Machinery