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NEMA and IEC Devices for Motor Service - A Guide for Understanding the Differences

NEMA

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ICS 2.4

NEMA AND IEC DEVICES FOR MOTOR SERVICE— A GUIDE FOR UNDERSTANDING THE DIFFERENCES

Published by:

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Foreword

Purpose of the Guide

The U.S. marketplace has seen a growing use of motor control products manufactured to International Electrotechnical Commission (IEC) standards and conventions (common practice). This has caused users to ask about differences between these products and the traditionally used products manufactured to the National Electrical Manufacturers Association (NEMA) standards and conventions (common practice).

Among issues raised by users are conformance to the National Electrical Code (NEC), listing of products by Underwriters Laboratories, Inc. (UL) and others, differences in ratings and performance, and application. Manufacturers have attempted individually to address these concerns, but because of the different philosophies behind IEC standards and NEMA standards and because of confusion between what is in the standard versus what is a conventional approach to the market, the answers themselves may be confusing. This document is an effort by manufacturers who are members of the NEMA Industrial Control and Systems Section (ICS) to provide consistent answers and to help users make sound selection decisions.

The following background information is pertinent:

1) NEMA ICS Standards philosophy includes standard electrical sizes, with defined ratings, intended to provide the user with a common basis for choosing the product, easier selection, and safe interchangeability. IEC Standards do not assign standardized electrical sizes or ratings, and instead, enable the manufacturer to assign his own ratings based on standardized test criteria.

2) There are published IEC standards and proposed new IEC standards, which, although not yet published as of this writing, are often referred to as though they are published. While standards do evolve, and while this document has attempted to address both the published and the proposed, it can only be considered current at the time it is published or revised.

3) Numerous conventions exist that reflect suppliers' response to perceived market needs for features and capabilities. As a result, conventions differ between starters and contactors designed for different markets. This document is intended to help the reader understand the differences between conventions and requirements, and between the standards themselves.

Finally, products manufactured to either standard are not mutually exclusive. The issue is to understand the differences and to select which product best suits an application. Proposed revisions to this Standards Publication should be submitted to:

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Scope

The features, conventions, characteristics and attributes identified in this guide are those of magnetic contactors and thermal overload relays. These are components which may be used alone, or combined with other components, to serve as full-voltage or reduced-voltage, reversing or non-reversing, single-speed or multi-speed motor controllers. Control products compared or contrasted in this Guide are those with equivalent electrical ratings; such ratings are expressed via nameplates, catalogues, or technical literature.

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A GUIDE FOR UNDERSTANDING THE DIFFERENCE

Section 1
GENERAL NEMA AND IEC DEVICES FOR MOTOR SERVICE

1.1 REFERENCED STANDARDS

In this publication, reference is made, in part or in full, to the standards listed below. Copies are available from the indicated source.

International Electrotechnical Commission
3, Rue De Varembè
1211 Geneva 20, Switzerland

IEC 158-1	*Contactors*
IEC 292-1	*Part 1: Direct-On-Line (Full Voltage) a.c. Starters*
IEC 947-1	*Part 1: General Rules*
IEC 947-4	*Contactors and Starters*

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ICS 2-1988	*Industrial Control Devices, Controllers and Assemblies*
ICS 2-110	*General Standards for Magnetic Controllers*
ICS 2-210	*General Standards for Magnetic Contactors*
ICS 2-222	*Overload Relays*
ICS 2-321	*Class A Controllers for Induction Motors rated in Horsepower*
ICS 2-327	*Class A Controllers for Induction Motors rated in Full-Load Current (FLC) and Locked-Rotor Current (LRC)*
ICS 1-1988	*General Standards for Industrial Control and Systems*

Underwriters Laboratories, Inc. Standards
333 Pfingsten Road
Northbrook, IL 60062-2096

UL 508	*Industrial Control Equipment*

1.2 MARKINGS

1.2.1 Nameplate Markings

Both NEMA and IEC motor starters and contactors have nameplates (labels) that list ratings to help the user select and apply the devices.

1.2.1.1 NEMA NAMEPLATE RATINGS

NEMA Size—A standardized rating system of sizes for motor controllers. For each NEMA Size, there are specifically assigned horsepower, voltage, frequency, and current ratings as defined by the NEMA /ICS Standards.

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Horsepower and Voltage—The maximum rating (in horsepower) at various voltages corresponding to the values assigned for each NEMA Size.

Continuous Current—the maximum current which an enclosed starter or contactor may be expected to switch and carry continuously without exceeding the temperature rises permitted by the NEMA Standard.

1.2.1.2 IEC NAMEPLATE RATINGS

HP and KW—The maximum rating for each stated operational voltage (U_e) and Utilization Category. The most common Kilowatt or HP ratings on a contactor or starter are for Utilization Category AC-3.

Utilization Category (Examples: AC-1, AC-3)—Describes the types of Service for which the controller is rated. (See 2.1).

Thermal Current (I_{th})—The maximum current which a contactor or a starter, each without its enclosure, may be expected to carry continuously without exceeding the temperature rises allowed by the IEC Standard. This is not a load switching rating.

Rated Operational Current (I_e)—The maximum FLC at which a motor starter or contactor may be used for a given combination of voltage, frequency and utilization category (AC-1, AC-3, etc). A device may have more than one operational current.

Rated Insulation Voltage (U_i)—A design parameter sometimes shown on the nameplate that defines the insulation properties of the controller. It is not used for selection or application.

Rated Operational Voltage (U_e)—The voltage at which each stated horsepower or kilowatt rating applies.

Standard Designation—The specific IEC Standard to which the product has been tested is required by IEC to be marked.

1.2.2 UL Markings

Underwriters Laboratories, Inc. policy permits any complying motor control product to be UL Listed, UL Recognized or UL Classified, and so marked.

A product that is UL Listed carries the UL Listing Mark (UL in a circle) on its nameplate adjacent to the ratings to which the UL Listing Mark applies. Adjacent to the UL Listing Mark are the words "Listed Industrial Control Equipment" or "Listed Ind. Cont. Eq". Listed industrial control equipment is suitable for installation with general use tools and for application at the ratings to which the Listing Mark is related. A UL Listed motor control product complies with the UL 508 Standard, and qualifies for installation under specific provisions of the NEC.

A motor control product that is UL Recognized may carry the UL Recognized Component Mark known as the "Backward UR", the printed letters U and R, joined and reversed as they would appear in a mirror. When used, according to UL, this mark must appear adjacent to the Manufacturer's identification and catalog number. UL Recognized equipment is not suitable for general use and must be combined with other items, under stated conditions of acceptability, into a product which, in turn, may be submitted to UL, become UL Listed, and carry the UL Listing Mark. The conditions of acceptability are published in the manufacturer's "UL Component Recognition Report."

A motor control product that is UL Classified carries the UL in a circle, the word Classified, and a notation that Underwriters Laboratories has evaluated the product with respect to compliance with a specific characteristic, standard, or part of a standard. UL's classification of a product to such a standard has no bearing on the product's ability to comply with UL 508, or to the NEC.

Not every function or rating shown on the nameplate of a UL Listed, Recognized or Classified product is qualified for use under all Articles of the NEC or necessarily meets all UL Standards. For example, a motor controller with magnetic trip provisions, listed under UL 508 as a motor controller, may not necessarily meet the requirements for listing under UL 489, Molded Case Circuit Breakers and Circuit Breaker Enclosures.

UL requires that where a contactor or starter carries a UL Listing Mark, only the ratings covered by that Listing Mark are to appear with the Mark on the nameplate. Other ratings, such as Kilowatt ratings, may be shown, but they must be appropriately segregated. Under certain circumstances UL allows the manufacturer to use a line as a means of separation between groupings of rating information to show that differentiation. Ratings adjacent to the UL Listing Mark relate to the Listing. Ratings shown on the opposite side of the line do not relate to the device Listing and do not qualify the device for general use in compliance with the NEC.

1.3 REFERENCES

For ease of reference, those contactors, overload relays, and starters designed to meet NEMA and UL Standards, with the traditional features and conventions initially provided primarily for the North American market, will be called traditional "NEMA" devices. Those contactors, overload relays, and starters designed to meet IEC Standards, with their associated traditional features and conventions, will be called traditional "IEC" devices. Many IEC devices conform to NEMA and UL Standards and are marked accordingly, differing only in conventions. Conversely, many NEMA devices conform to IEC Standards, and may be marked accordingly, differing only in conventions.

1.4 CONVENTIONS

Practices followed by a majority of manufacturers selling in a given market have resulted in features and charac-

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teristics which are associated with either NEMA or IEC devices. This Guide attempts to identify those resulting conventions as design philosophies. It also identifies differences in standards, where differences exist.

A convention, as used in this Guide, is a commonly accepted practice, expected by the user, that is widely adopted, but is not provided for in written standards.

1.5 DESIGN PHILOSOPHIES

1.5.1 Traditional NEMA Contactors

A NEMA contactor is designed to meet the size rating specified in NEMA Standards. A philosophy of the NEMA Standards is to provide electrical interchangeability among manufacturers for a given NEMA Size. Since the installer often orders a controller by the motor horsepower and voltage rating, and may not know the application or duty cycle planned for the motor and its controller, the NEMA contactor is designed by convention with sufficient reserve capacity to assure performance over a broad band of applications without the need for an assessment of life requirements. Other conventions are that the contacts for most NEMA contactors are replaceable when inspection shows the need and that molded (encapsulated) coils are common on most NEMA devices.

1.5.2 Traditional IEC Contactors

IEC Standards do not define standard sizes. An IEC rating, therefore, indicates that a contactor has been evaluated by the manufacturer or a laboratory to meet the requirements of a number of defined applications (utilization categories).

The goal of the IEC design philosophy is to match a contactor to the load, expressed in terms of both rating and life. Usually, the user or original equipment manufacturer, who require motors and controllers for their specific application, are in the best position to make this match. Typically, the contacts for larger horsepower-rated IEC contactors are replaceable. Most smaller horsepower-rated contactors do not have replaceable or inspectable contacts and are intended to be replaced when their contacts weld or are worn beyond further use. Most IEC contactors are supplied with tape-wound coils.

1.5.3 NEMA Thermal Overload Relays

NEMA thermal overload relays generally accept field installable current elements, often called "heaters", as shown in Figures 1-1 and 1-2. Current element selection and installation is made after the motor full-load current (FLC) is known. A given overload relay will accept different current elements, according to the FLC applicable to the contactor size with which the overload relay is mated. Current elements can be installed or changed without re-wiring the motor controller. Thus, a single NEMA overload relay, with appropriate heaters, generally provides overload protection for numerous motor currents and service factors.

NEMA thermal overload relays use bimetals or eutectic alloys as the heat sensing means within the overload relay. These indirectly heated heat-sensing means are not a part of the current path from the contactor to the motor. Indirectly heated overload relays allow more time than directly heated sensors for a motor and its associated load to accelerate to rated speed. To accommodate motor acceleration variables, overload relays are available for trip Classes 10, 20, and 30.

Two inherent attributes of the separate current element design philosophy are that such heaters tend to have a higher short-circuit withstand capability than directly-heated sensors for the same motor, and that interchangeable heaters allow one overload relay to cover the entire current range of the motor controller.

1.5.4 IEC Thermal Overload Relays

IEC thermal overload relays, see Figure 1-3, are typically designed with directly-heated, bimetal elements, where the heater and bimetal are integral and are usually Class 10 (See 4.3.1). Typically, they have an adjustment dial or lever, marked in amperes relating to FLC. They typically have ranges of current where the maximum FLC setting is between 1.3 and 1.7 times the minimum FLC setting. The user adjusts the dial of the OLR to his motor's FLC, or in accordance with the manufacturer's instructions.

If a different current range is required, or if the heater must be replaced, the overload relay must be changed. Several overload relays are required to cover the entire current range of the associated contactor rating because of the narrow current range. This reduces the number of choices among short-circuit protective devices that may be used in the motor branch circuit.

1.5.5 NEMA Motor Controllers

NEMA contactors and overload relays are assembled into motor controllers consisting of one or more contactors on a common base plate, combined with one or more overload relays, complete control-circuit wiring (except for connections to remote components) and complete power circuits from line terminals to load terminals. Terminals are included for field wiring and are designed so that the factory wiring is not disturbed by the installer's connection to line, load, or remote control-circuit devices.

1.5.6 IEC Motor Controllers

Typically, IEC motor controllers are not factory wired and are assembled after delivery. Assembly includes mounting the individual contactors and overload relays, possibly to a DIN rail, furnishing and installing all control-circuit wiring, and sometimes furnishing additional power-circuit conductors and wire connectors.

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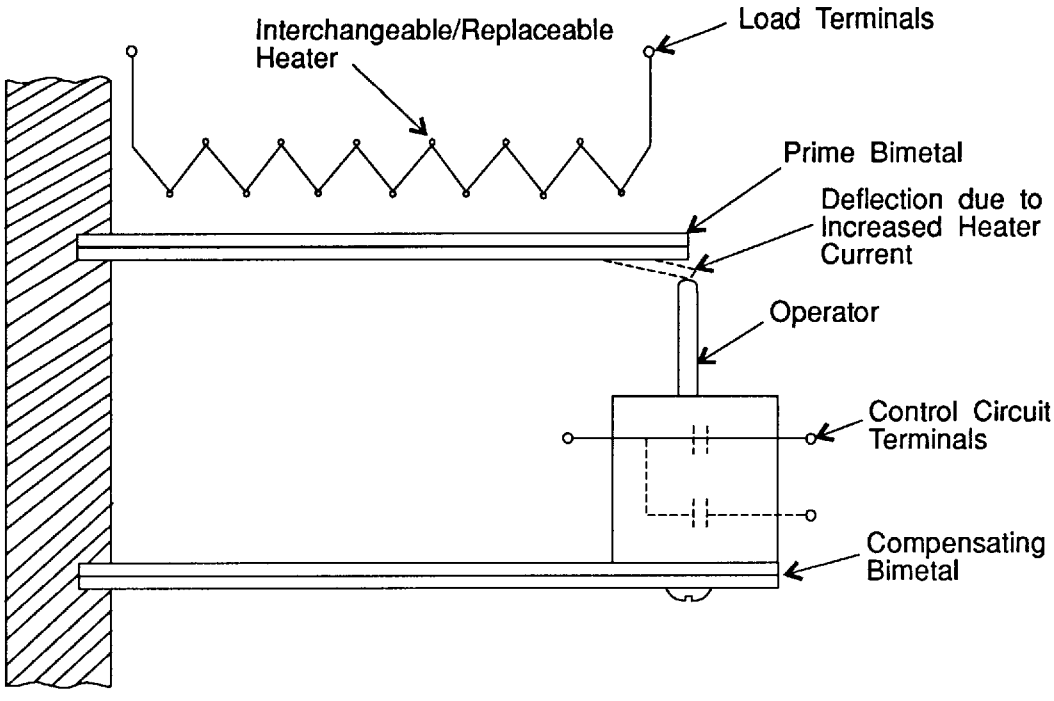


Figure 1-1
NEMA OVERLOAD RELAY WITH INDIRECTLY HEATED BIMETAL AND HEATER

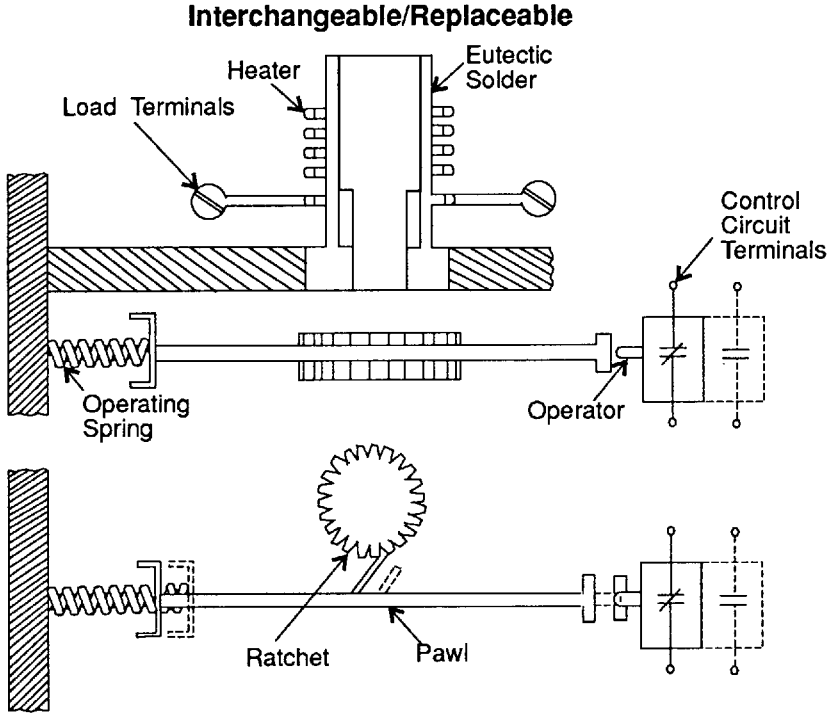


Figure 1-2
NEMA MELTING ALLOY OVERLOAD RELAY WITH HEATER

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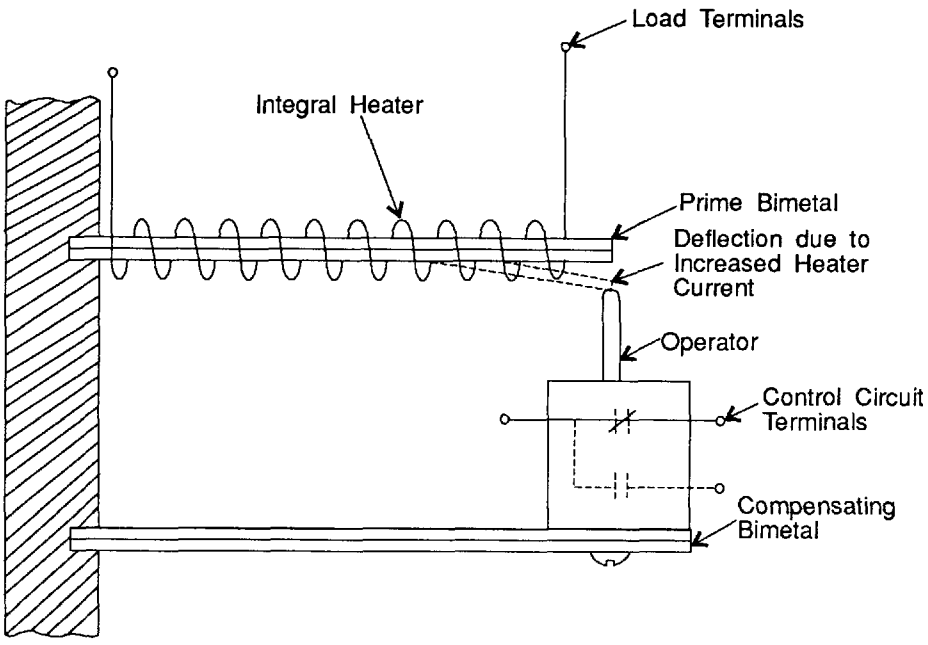


Figure 1-3
IEC BIMETAL OVERLOAD RELAY WITH NON-REPLACEABLE HEATER

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Section 2
SELECTION CONSIDERATIONS

2.0 SELECTION CONSIDERATIONS

Coordination of motor and starter is essential for each motor application. This Section assists the installer/user in this coordination.

2.1 UTILIZATION CATEGORIES

Utilization Category is an IEC term used to describe a specific type of application. The scope of this Guide limits the discussion of utilization categories to motor applications only, but also includes a description of Utilization Category AC-1, since most IEC contactors include this utilization category on their nameplates. For simplicity, Utilization Category AC-2 is also not a part of this comparison because the slip-ring motors covered by AC-2 are a small percentage of the motor population. Table 2-1 lists the most common utilization categories applicable to contactors.

Convention has led to the assignment of several ratings to a given contactor for different utilization categories and voltages. The electrical system designer chooses which of several devices he or she prefers for the application, based on its ability to meet, or exceed, the required horsepower, voltage ratings, and other factors, including performance. This technical data will be available in literature. IEC contactors used in the U.S. are usually marked with voltage values (U_e) and with Horsepower (or Kilowatt) ratings, for use with the maximum AC-3 rated operational current (I_e). IEC Contactor selection is based on the percent that jogging and plugging (AC-4) is of non-jogging and non-plugging (AC-3) conditions in the duty cycle and desired contact (electrical) life. In general, any time the duty cycle includes significant jogging or plugging, a larger size IEC contactor is selected than would be needed for pure AC-3 applications.

Table 2-1
Common Utilization Categories for AC Contactors*

UTILIZATION CATEGORIES	TYPICAL APPLICATIONS
AC-1	Non-inductive or slightly inductive loads, e.g., resistive furnaces.
AC-3	Squirrel cage motors, starting and switching off while running at rated speed.** Make locked-rotor current and break full-load current. Occasionally jog.**
AC-4	Squirrel cage motors, starting and switching off, while running at less than rated speed. Jogging (inching) and plugging (reversing direction of rotation from other than an off condition). Make and break locked-rotor current.

* This table is based on Table I of IEC Publication 947-4.

** AC-3 category may be used for occasional inching (jogging) or plugging for limited time periods such as machine set up; during such limited time periods the number of operations should not exceed five per minute nor more than ten in a 10-minute period.

2.2 CONTACTOR ELECTRICAL LIFE

Neither IEC nor NEMA Standards specify electrical life performance requirements or require that such data be published by the manufacturer. Most manufacturers use test parameters specified in the IEC Standards for life testing both NEMA and IEC devices, and will provide test data upon request. Such data is not intended to be and should not be considered a guarantee of life expectancy on a specific application. Failure criteria, test result interpretation parameters, and many of the actual test parameters are not specified in either standard.

Readers should note that:

- Data provided by different manufacturers may not be equivalent.
- Data is generally based on the manufacturer's tests plus calculations and extrapolations to voltages and currents at which tests were not actually run.
- Lastly, laboratory test conditions do not necessarily duplicate the conditions present on a specific application.

In addition, experience has shown that devices from the same manufacturer do not have identical life, and therefore life figures would have to be expressed in statistical terms and probabilities.

A conservative approach should be used when utilizing such data to apply devices, until experience is gained on the specific application.

Users of contactors may wish to consider running their own verification tests based on the conditions of their known application.

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2.2.1 Electrical Life Test Parameters

Electrical life tests are conducted based on a set of laboratory test parameters published in IEC Publication 158-1 and IEC Publication 947-4.

Example: A contactor is to be tested for the AC-3 Utilization Category.

The IEC test for AC-3 is set up so that the contacts make six times the motor full load current (FLC) at the full rated voltage. They then break the motor full-load current at one-sixth of rated voltage to take into account the back voltage generated by the motor in its running condition.

The IEC test for AC-4 reflects duty far more severe than that for AC-3 applications. While the contacts must still be able to make *six* times the motor full-load current at rated voltage, they now must also break *six* times the motor full-load current, and do so at full rated voltage.

Depending on the device and the voltages, such an increase in duty severity will significantly reduce the electrical life of the contactor to as little as 2% of its AC-3 life. (See example, as shown in 2.2.2.2).

In normal circumstances, for any application with such a high level of AC-4 content, a larger IEC device would be selected to ensure adequate electrical life, while a NEMA device would be selected based on derating in accordance with Tables 2-2 and 2-3. A product of conventional NEMA construction will generally have less of a physical size change as a result of derating for AC-4 application.

2.2.2 How To Use Electrical Life Curves

Manufacturers of IEC devices publish electrical contact life curves for a family of contactors, for the purpose of selecting which contactor from a manufacturer's product line is the appropriate choice for a defined application. These curves are not intended to predict the actual life of a particular member of the product line in a particular application but are intended to give an indication of the relative life of the products. The lack of standard criteria for failure requires that the user should take care in using these curves to compare contactors made by different manufacturers.

2.2.2.1 EXAMPLE, AC-3 LIFE

Figure 2-1 is an example of an AC-3 life-load curve. The x-axis represents various horsepowers at 460V. The y-axis represents switching cycles in millions. For this example, hypothetical contactor sizes are listed at the top of the graph. Assume that a contactor is required to control a 10 HP motor at 460V in an AC-3 application. Several options are available. If one million laboratory operations is considered appropriate for the application, a Contactor C would suffice. However, the curves indicate laboratory contact life for other contactor sizes controlling a 10 HP motor as follows:

- Contactor D can be switched 1,900,000 times.
- Contactor E can be switched 3,100,000 times.
- Contactor F can be switched 6,000,000 times.

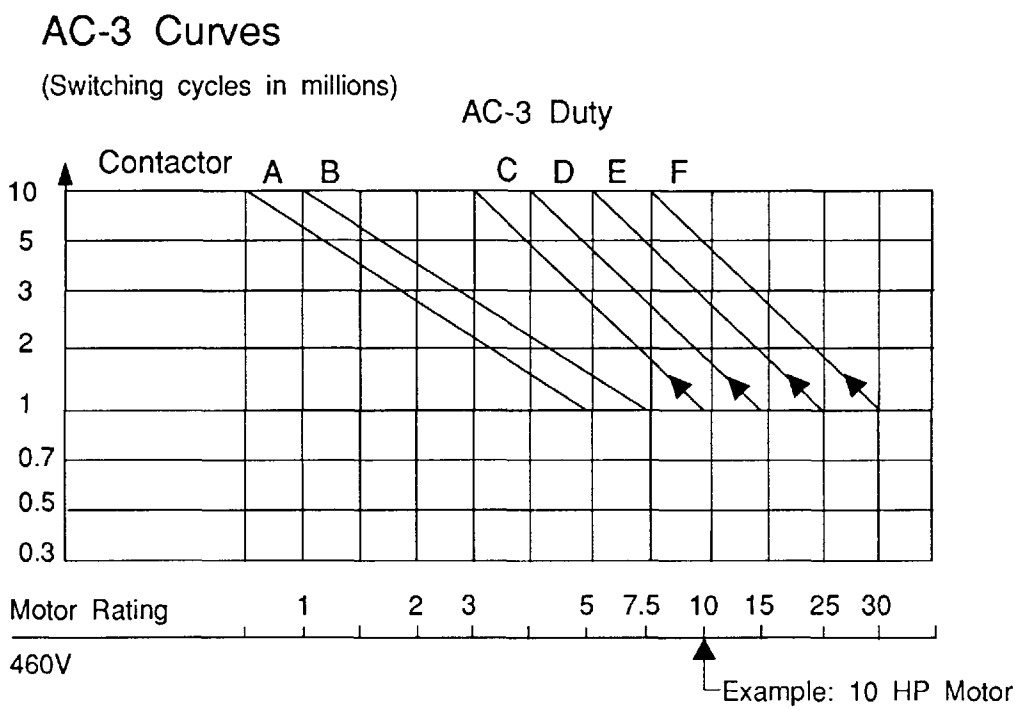


Figure 2-1
EXAMPLE OF IEC AC-3 ELECTRICAL LIFE CURVES

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It is unsafe to use these curves at horsepower ratings exceeding the manufacturer's claimed maximum HP rating for a specific voltage and utilization category. No contactor should be applied above its claimed maximum horsepower or current rating because the locked rotor and thermal capability of the contactor may be exceeded.

For IEC contactors rated below 50 HP, many manufacturers have stated that these contactors can perform one million AC-3 operations and 10 million mechanical operations during the life of the contactor.

2.2.2.2 EXAMPLE, AC-4 LIFE

Figure 2-2 is an example of an AC-4 electrical life curve. The axes in the curve represent the same functions as those shown in the AC-3 curve, but, in this case, the values on the Y-axis are different because the application is different. A comparison of the AC-3 curve with the AC-4 curve shows that the contactor's switching cycles are reduced in AC-4 applications, because of the severe test conditions imposed for the AC-4 utilization category.

Assume that a 10 HP 460V motor is switched by a reversing controller without anti-plugging controls. Each reversing controller consists of two identical contactors. The operating conditions are those of utilization category AC-4, because the rapid changes in direction of rotation (plugging) invoke additional current greater than the motor full-load current. The curves for utilization category AC-4 indicate laboratory contact life as follows:

- Contactor C can be switched 20,000 times.
- Contactor E can be switched 150,000 times.
- Contactor F can be switched 270,000 times.

Note that the estimated life of Contactor C in the AC-4 example is 20,000 switching cycles, which is 2% of the 1,000,000 switching cycles in the AC-3 example.

The user should not exceed the maximum AC-4 HP rating claimed for the device. Since an AC-4 rating might not be listed on a device, the manufacturer's published literature should be consulted.

2.3 MIXED OPERATION LIFE FOR CONTACTORS USING IEC PROCEDURE

An approximation for laboratory contact life of mixed AC-3 and AC-4 can be obtained by using the formula:

$$M = \frac{A}{1 - \left(\frac{c}{100}\right) + \left[\left(\frac{c}{100}\right) \times \left(\frac{A}{B}\right)\right]}$$

Where:

M = Laboratory contact life on mixed operations in switching cycles.
A = Laboratory contact life on AC-3 operation in switching cycles.
B = Laboratory contact life on AC-4 operation in switching cycles.

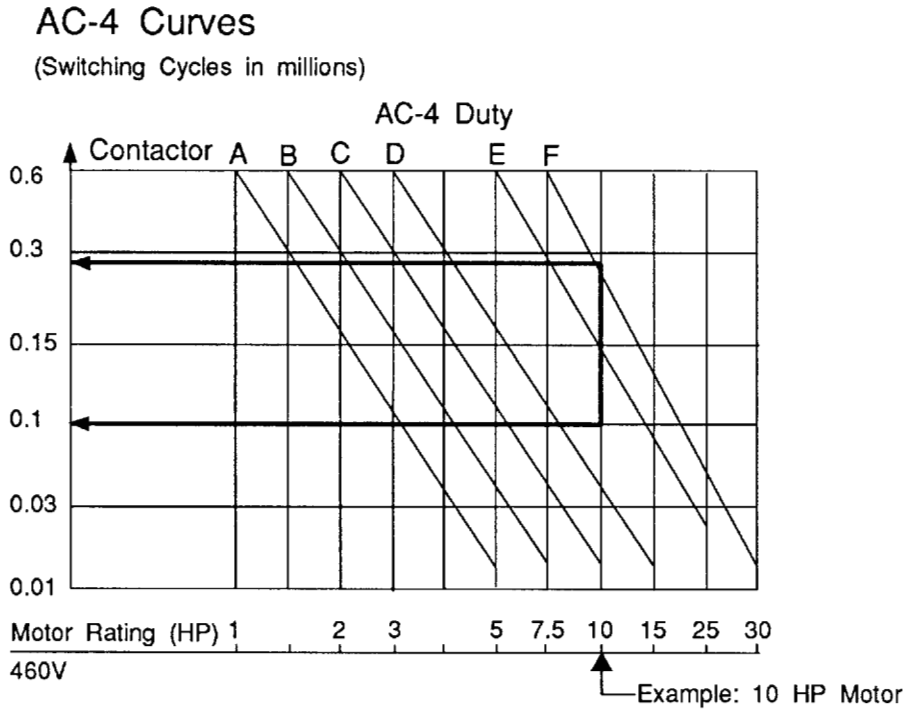


Figure 2-2
EXAMPLE OF IEC AC-4 ELECTRICAL LIFE CURVES

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C = Proportion, expressed as percentage, of AC-4 operations for the application to total operations.

For example, assuming an AC-3 laboratory life of 1,000,000 operations, and an AC-4 laboratory life of 20,000 operations, mixtures of AC-3 and AC-4 operations would affect the laboratory contact life of contactors as follows:

M = Unknown
A = 1,000,000 (Assumption, for these examples; see Figure 2-2)
B = 20,000 (Assumption, for these examples; see Figure 3-1)
C = computed each case, below. (AC-4 operations as a percentage of total operations)

CASE	C	Expected Laboratory Contact Life, M (Switching Cycles)
1. 100% AC-3 Operations	0%	1,000,000
2. 1 AC-4 Operation in 1,000 total operations	0.1%	950,000
3. 1 AC-4 Operation in 100 total operations	1.0%	670,000
4. 5 AC-4 Operations in 100 total operations	5.0%	290,000
5. 10 AC-4 Operations in 100 total operations	10.0%	170,000

The examples demonstrate how contact life decreases as the percentage of AC-4 operations increases.

2.4 HOW TO USE NEMA CONTACTOR RATINGS

Traditional NEMA contactors are designed to be sufficiently rugged to assure performance over a broad band of applications without the need for an assessment of life requirements.

NEMA Standard, ICS 2 parts 2-321 and 2-327, assign Standard ratings to eleven sizes of motor starters and contactors. The ratings in Table 2-2 apply when these NEMA controllers are used for pure AC-3 applications, or for a mixture of AC-3 and AC-4 applications, where the AC-4 application is limited to five openings per minute and not more than ten openings in any ten-minute period. For jogging and plugging (AC-4) applications in excess of the limits described above, NEMA controllers are derated to the ratings shown in Table 2-3, to increase electrical life. The user should not exceed the maximum jogging horsepower rating claimed for the device (Table 2-3). Since a jogging duty rating might not be listed on a device, the manufacturer's published literature should be consulted.

2.5 ENVIRONMENTAL FACTORS

Environmental and installation factors such as altitude, humidity, chemicals, shock, vibration, mounting means, high ambient temperature, and voltage fluctuations can alter the life and rating of any contactor. Therefore, technical data from the manufacturer, in addition to published ratings or electrical lifecurves, may be needed to provide for the application of a contactor where the effect of any of these factors is unusual.

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Table 2-2
RATINGS FOR THREE-PHASE SINGLE-SPEED FULL-VOLTAGE MAGNETIC CONTROLLERS FOR NON-PLUGGING AND NON-JOGGING DUTY

Size of Controller	Continuous Current Rating** Amperes	Horsepower* at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 or 575 Volts	Service-limit Current Rating** Amperes
00	9	1 1/2	1 1/2	1 1/2	2	11
0	18	3	3	5	5	21
1	27	7 1/2	7 1/2	10	10	32
2	45	10	15	25	25	52
3	90	25	30	50	50	104
4	135	40	50	75	100	156
5	270	75	100	150	200	311
6	540	150	200	300	400	621
7	810	...	300	...	600	932
8	1215	...	450	...	900	1400
9	2250	...	800	...	1600	2590

*These horsepower ratings are based on the locked-rotor current ratings given in ICS 2, Table 2-327-1. For motors having higher locked-rotor currents, a larger controller should be used so that its locked rotor current rating is not exceeded. (This note is approved as Authorized Engineering Information).

**The continuous-current ratings represent the maximum rms current, in amperes, which the controller shall be permitted to carry continuously without exceeding the temperature rises permitted by Part 1-109 of NEMA Standards Publication No. ICS 1. The service limit current ratings represent the maximum rms current, in amperes, which the controller shall be permitted to carry for protracted periods in normal service. At service-limit current, temperature rises may exceed those obtained by testing the controller at its continuous current rating.

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TABLE 2-3
RATINGS FOR THREE-PHASE SINGLE-SPEED FULL-VOLTAGE MAGNETIC CONTROLLERS FOR PLUG-STOP, PLUG-REVERSE OR JOGGING DUTY

Size of Controller	Continuous Current Rating** Amperes	Horsepower* at 60 Hertz 200 Volts	60 Hertz 230 Volts	50 Hertz 380 Volts	60 Hertz 460 or 575 Volts	Service-limit Current Rating** Amperes
0	18	1 1/2	1 1/2	1 1/2	2	21
1	27	3	3	5	5	32
2	45	7 1/2	10	15	15	52
3	90	15	20	30	30	104
4	135	25	30	50	60	156
5	270	60	75	125	150	311
6	540	125	150	250	300	621

*These horsepower ratings are based on the locked-rotor current ratings given in ICS 2, Table 2-327-3. For motors having higher locked-rotor currents, a larger controller should be used so that its locked-rotor current rating is not exceeded. (This note is approved as Authorized Engineering Information).

**The continuous-current ratings represent the maximum rms current, in amperes, which the controller shall be permitted to carry continuously without exceeding the temperature rises permitted by Part 1-109 of NEMA Standards Publication No. ICS 1. The service limit current ratings represent the maximum rms current, in amperes, which the controller shall be permitted to carry for protracted periods in normal service. At service-limit current, temperature rises may exceed those obtained by testing the controller at its continuous current rating.

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Section 3
TERMINAL MARKING AND WIRING CONVENTIONS

3.1 GENERAL

Users of both NEMA and IEC type devices should, in all cases, follow the manufacturer's wiring diagrams supplied with the equipment to assure proper connection of the controller to the load.

Manufacturers of NEMA type starters and contactors follow the NEMA standard marking.

Most IEC type starters and contactors supplied for the American market incorporate the NEMA standard terminal identification marking. Many also retain conventional IEC terminal marking as additional marking on the device.

Imported machines utilizing IEC style devices might incorporate only the IEC marking.

See Figures 3-1 and 3-2.

3.2 NORTH AMERICAN CONVENTION

In the USA and Canada the most commonly accepted wiring practice is to connect all terminals together that have the same terminal marking. For example, in power circuits, the terminal marked T1 on the controller is connected to the terminal marked T1 on the motor and, in control circuits, terminals marked 1, 2 and 3 on the controller are connected to terminals 1, 2 and 3 on the remote control station.

3.3 IEC CONVENTIONS

IEC devices have power terminals marked 1,3,5 and 2,4,6, corresponding in function to L1,L2,L3, and T1, T2,T3 on NEMA Controllers.

Control circuit terminals on IEC style devices carry two digit terminal markings, the first digit signifying location and the second the control device function.

Terminals of IEC devices carrying the same designation are not usually connected together.

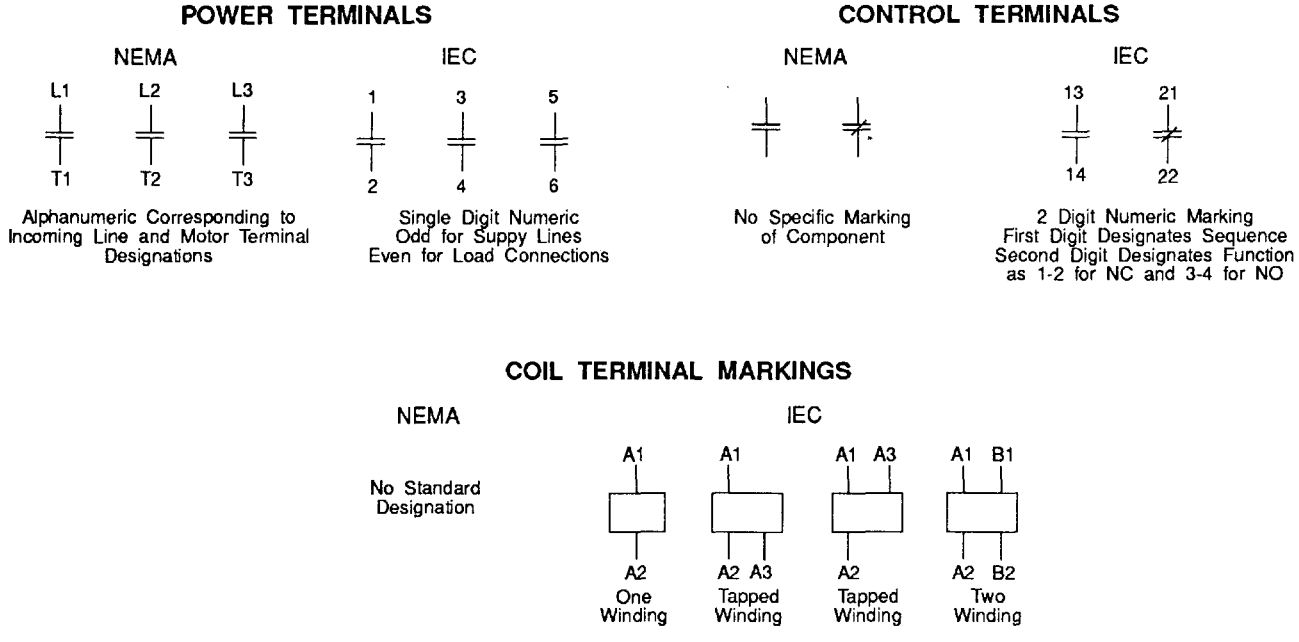
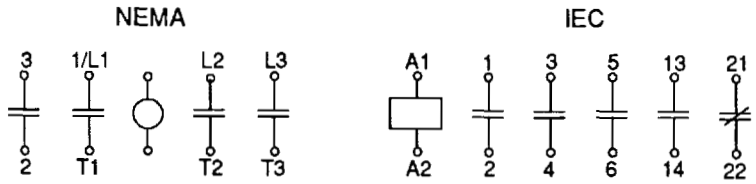


Figure 3-1
NEMA AND IEC CONVENTIONAL TERMINAL MARKINGS

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TYPICAL CONTROLLER MARKING



TYPICAL SCHEMATIC DIAGRAM

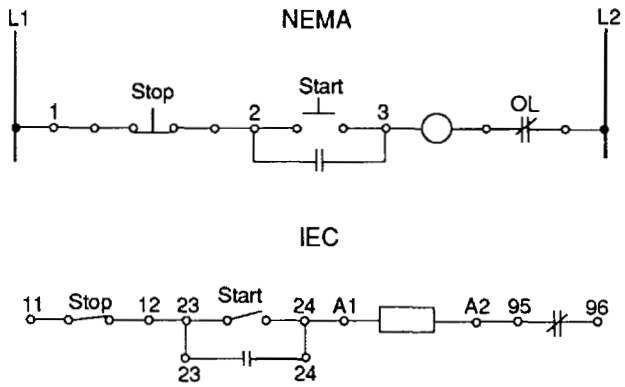


Figure 3-2
NEMA AND CONVENTIONAL IEC CONTROLLER MARKING AND SCHEMATIC DIAGRAM

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Section 4
COMPARISONS

4.1 PHYSICAL CHARACTERISTICS

Traditional NEMA starters and contactors in general are larger, more rugged, and have a greater short-circuit withstand capability for a given horsepower rating.

IEC starters and contactors, in general, being smaller, occupy less panel space than NEMA devices for the same AC-3 application.

Because of required derating factors, there may not be significant size differences between NEMA and IEC devices when the application includes significant AC-4 content.

4.2 ELECTRICAL LIFE

When tested in the laboratory with identical, pure, IEC AC-3 loads of 50 HP or less, conventional NEMA contactors will usually (but not in all cases) exceed IEC contactors in electrical life for contactors with identical AC-3 ratings. When the test load includes more than occasional AC-4 content, conventional NEMA contactors demonstrate substantially longer life than IEC contactors of the same rating.

4.3 OVERCURRENT PROTECTION

NEMA and IEC starters and overload relays are available in Class 10, 20, and 30 configurations. (See ICS 2, Part 2-222). NEMA starters are normally supplied as Class 20 unless otherwise specified. IEC starters are normally supplied as Class 10 unless otherwise specified.

4.3.1 Overload Relay Class Applications

Most NEMA-rated general purpose motors will be protected by a Class 20 (standard trip) overload relay selected in accordance with the control manufacturer's instructions. Class 10 overload relays will also protect a general purpose motor when the load permits the motor to reach rated speed. Class 10 (fast trip) overload relays are also used for hermetic refrigerant motor-compressors, submersible pumps, and similar applications. Class 30 (slow trip) overload relays may be needed for special motors driving high inertia loads, such as ball mills, reciprocating pumps, loaded conveyors, and the like.

4.3.2 Motor Acceleration Time

A key ingredient in protecting a motor is the selection of the Class of overload relay for the acceleration time of the motor as well as for its FLC. An overload relay may trip before the motor accelerates to its full rated speed if the motor starting current extends at any point beyond the overload relay trip curve.

The time required for an overload relay to trip under locked-rotor (stalled) motor conditions is ideally the time that permits attainment of the available motor horsepower and starting torque; in other words, the overload relay allows sufficient time for the motor and its load to accelerate to rated speed. Nuisance tripping occurs when an overload relay, or its heater, or its adjustment, is selected so that the motor does not reach operating speed or perform at its ratings. This may cause the user to install the next higher rated overload relay, resulting in reduced protection.

For overload relays having interchangeable current elements (heaters) Section 430-34 of the NEC permits a user to install a heater one size larger than appropriate for the motor FLC, under certain conditions. These are (a) when the properly selected element trips before the motor can accelerate to rated speed, and (b), provided the next size element has a rating not greater than 130% of motor FLC for service factor 1.0 motors, or not greater than 140% of motor FLC for motors with a service factor of 1.15. Rather than give up running protection, a user should select a higher class of overload relay, which would provide more time for motor and load to accelerate, and yet retain the 115% or 125% level of overload protection specified by the NEC.

Where a directly-heated bimetallic or other adjustable overload relay trips before the motor has accelerated to rated speed, the NEC permits the variable current setting to be changed to some value higher than the motor FLC. For example, if this setting is 10% higher than rated FLC, overcurrent protection could become as high as 132% of motor FLC, which sacrifices running protection. Where a high inertia load can be anticipated, replace the adjustable overload relay with one having a higher class designation. One form of such an overload relay has a saturable current transformer or other device in the circuit feeding the overload relay heating element. Such a transformer or device limits the inrush current to the heating element and thus converts a Class 10 overload relay to Class 20 or 30.

4.3.3 Short-Circuit Withstand

Part D of Article 430 of the NEC covers the selection of motor branch circuit, short-circuit and ground fault protective devices that are intended to protect the wiring, the motor starter and the motor from overcurrent caused by short circuits or grounds. Motor controllers listed by industry accepted, independent laboratories have been subjected to short circuit tests consistent with Article 430. If a motor controller has passed those tests without qualification, it will show the laboratory listing mark without restrictions. If a device is unable to pass the test with the maximum value short circuit and ground fault protective device allowed by the NEC, it may be tested and qualified

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with a protective device of a smaller value. That starter may then be listed, but safety standards require that a restriction must be shown on the overload relay, or on the instructional materials packaged with the starter. Any statement on the overload relay, or in the instruction materials, relating to a short circuit and ground fault protective device should be considered a restriction. For example, any statement regarding a maximum fuse limits the device to use with that fuse, or one having superior short circuit clearing capabilities.

Most traditional IEC contactors utilize current carrying parts of a lesser mass than those used in similarly rated traditional NEMA type contactors. Moreover, IEC type overloads generally use directly heated bimetals rather than the indirectly heated current sensing elements typically used in NEMA type overloads. As a result, IEC type devices generally have a lesser short circuit withstand capability than similarly rated NEMA type devices. Generally speaking, selecting an IEC type starter will limit the selection of short circuit and ground fault protective devices to a greater degree than will a traditional NEMA starter used in the same application.

4.4 PHASE-LOSS PROTECTION

"Phase-loss" as used in this document means the loss of one phase supplying a single three-phase motor, such as when one fuse opens in the motor branch circuit. When a phase is lost in a feeder circuit supplying two or more three-phase motors, the result is a phase imbalance, rather than a phase loss in each motor branch circuit.

Neither an IEC nor NEMA type thermal overload relay is intended to provide phase imbalance protection. The user should specify a product specifically intended for this purpose to provide protection against "phase imbalance". Overload relays do, however, provide protection against "phase-loss".

Most three-phase thermal overload relays offer some degree of phase loss protection and in order to be a Listed product, safety standards require that they must do so. Convention, rather than the standards themselves, account for most of the differences in construction that exist between IEC and NEMA overload relays. The convention in North America, and hence in the typical NEMA product, has been to use eutectic alloy devices for hand reset thermal overload relays which have an individual heat sensing element in each phase that is mechanically linked to a common trip mechanism. With the high trip forces used in such a device, an overload in any phase is sufficient to trip the relay, irrespective of the condition of the other phases. This convention has typically been followed for the use of bimetallic thermal overload relays to the NEMA standard, in that each phase is capable of tripping independently of the other two. As a result, both types of device provide single phase protection to the degree that, if a phase is lost, the load on the motor is usually sufficient to cause overload currents in the remaining phases or to stall the motor, with the same net result of tripping the overload relay. In the event that the motor is so lightly loaded that it can continue to operate on single phase, without excessive currents being drawn, then the motor will not overheat and the overload relay will not trip. Of course, a trip will occur when a re-start is attempted.

Conversely, the convention of IEC thermal overload relays has been for them to be bimetallic devices, where the tripping forces are derived by adding together the individual phase forces. The loss of current in one phase, and the resultant reduced tripping force, causes the device to require higher than normal tripping currents in the remaining phases. To compensate for this loss, a mechanism, called "differential action" is used in nearly all IEC thermal overload relays. It adds the force developed by the cooling of the bimetal in the lost phase to the force developed by the heating of the bimetals in the other two phases to develop the total force required for tripping. Manufacturers of these products can design to have the cooling force component have a larger influence than the heating force, and hence produce a product that trips when a phase is lost with lower than normal currents in the remaining phases.

4.5 TERMINAL TEMPERATURE RISE

Traditional NEMA starters and contactors are designed for use with 60°C temperature wire with a corresponding allowable 50°C terminal temperature rise.

Typically, IEC starters and contactors, and those NEMA starters and contactors so marked, require 75°C temperature wire with a corresponding 65°C allowable terminal temperature rise when UL Listed. Controller temperature rise requires consideration when an enclosure is selected.

When one type of controller is replaced with the other, the existing wire size, and wire temperature rating, need to be considered.

4.6 CONSTRUCTION

NEMA motor starters and contactors typically have the coil-holding-circuit auxiliary contact located on the viewer's left-hand side. IEC contactors typically locate this auxiliary contact on the right.

NEMA magnetic motor starters and contactors typically use more coil power, have larger magnets, larger contacts, and stronger contact springs, and have higher short-circuit-withstand capability. IEC devices, generally being smaller, consume less coil power.

IEC devices up to 20 HP, can be mounted on an IEC Standard (DIN) 35mm rail. This DIN rail mounting permits snap-on interchangeability of one brand of IEC device with another, without additional drilling. IEC

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devices up to 10 HP, by convention, are generally the same width for the same rating.

NEMA has no conventions relating to standard mounting rail, standard widths, nor standard mounting dimension.

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Section 5
LIST OF ABBREVIATIONS

AC-1 A type of non-inductive contactor load. See Table 2-1.

AC-3 A squirrel-cage motor load, without plugging or jogging. See Table 2-1.

AC-4 A squirrel-cage motor load, all plugging or jogging. See Table 2-1.

C Temperature expressed in degrees Celcius.

DIN Deutsche Ingenieurwesen Normen (German Engineering Standard).

FLC Motor full-load current expressed in amperes.

HP Horsepower, as an electric motor output rating.

IEC International Electrotechnical Commission.

I_e Rated Operational current. See Paragraph 1.2.2.

I_{th} Rated thermal current. See Paragraph 1.2.2.

kW Kilowatts, as an electric motor output rating.

LRC Motor locked-rotor current expressed in amperes.

mm Millimeter (approximately .040 inch).

NEC National Electrical Code.

NEMA National Electrical Manufacturers Association.

U_e Rated operational voltage. See Paragraph 1.2.2.

U_i Rated insulation voltage. See Paragraph 1.2.2.

UL Underwriters' Laboratories, Inc.

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Standardization Policies and Procedures, p. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 2)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 8)

Categories of Standards

National Electrical Manufacturers Association Standards are of three classes:

1. NEMA Standard, which relates to a product, process or procedure commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp 7 & 16)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.

(Standardization Policies and Procedures, pp. 7 & 16)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon. *(Standardization Policies and Procedures, pp 7 & 16)*

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

July 17, 1990

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