Data Bulletin

Wire Temperature Ratings and Terminations

INTRODUCTION

Many electrical inspectors can tell you that confusion about wire temperature ratings and equipment termination temperature requirements results in their rejecting installations. Information about this topic can be found in the National Electrical Code® (NEC®), testing agency directories, product testing standards, and manufacturers' literature, but many people do not consult these sources until it is too late.

WHY ARE TEMPERATURE RATINGS IMPORTANT?

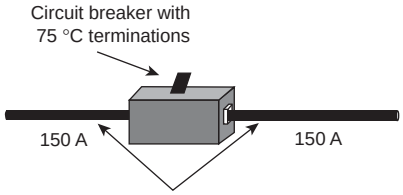
Conductors carry a specific temperature rating based on the type of insulation used on the conductor. Common insulation types can be found in Table 310.13 of the NEC, and corresponding ampacities can be found in Table 310.16. Table 1 shows the ampacity of a 1/0 copper conductor based on different conductor insulation types.

Table 1: Ampacity of a 1/0 Copper Conductor with Different Insulation Types

Insulation Type	Temperature Rating	Ampacity
TW	60 °C	125 A
THW	75 °C	150 A
THHN	90 °C	170 A

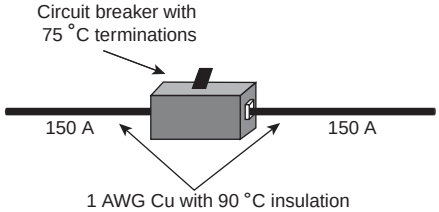
The ampacity of the 1/0 Cu conductor depends on the temperature rating of the insulation. At the same ampacity, a smaller conductor with higher-rated insulation can be used instead of a larger conductor with lower-rated insulation. As a result, the amount of copper and even the number of conduit runs needed for the job may be reduced.

One of the most common misapplications of conductor temperature ratings occurs when the established temperature rating of the equipment termination is ignored. This is particularly true for equipment rated for 600 V and less since the equipment is tested as a complete system using conductors sized by the NEC rules. Reduced conductor sizes result in the system having less ability to dissipate heat and therefore increase the operating temperature of the equipment terminations. Conductors must be sized by considering where they will terminate and how that termination is rated. If a termination is rated for 75 °C, the maximum temperature at that termination is 75 °C when the equipment is loaded to its ampacity. If 60 °C insulated conductors are used in this example, the additional heat at the connection above 60 °C could result in conductor insulation failure.



Note: Conductor properly sized based on the termination rating of the circuit breaker.

Figure 1: Properly Sized Conductor



Note: Conductor properly sized based on the termination rating of the circuit breaker.

Figure 2: Improperly Sized Conductor

When a conductor is selected to carry a specific load, the user/installer or designer must know the termination ratings for the equipment in the circuit. For example, consider a circuit breaker with 75 °C terminations and a 150 A load. If a THHN (90 °C) conductor is chosen for the job, review Table 310.16 in the NEC and look for a conductor that will carry the 150 A. Although a 90 °C conductor is being used, ampacity must be chosen from the 75 °C column because the circuit breaker termination is rated at 75 °C. Based on the table, a 1/0 copper conductor is acceptable. The installation would be as shown in Figure 1, with proper heat dissipation at the termination as well as along the conductor length. Had the temperature rating of the termination not been a consideration, a 1 AWG conductor might have been chosen, based on the 90 °C ampacity. This may have led to overheating at the termination or premature opening of the overcurrent device due to the smaller conductor size (see Figure 2).

In this same example, a conductor with a 75 °C insulation type (THW, RHW, USE, etc.) also would be acceptable since the termination is rated at 75 °C. A 60 °C insulation type (TW) is not acceptable since the temperature at the termination could rise to a value greater than the insulation rating.

THE NEC RULES

Equipment Rated for 100 A or Less— NEC 110.14(C)(1)(a) items 1 through 4

NOTE: The equipment sizes and ampacities shown in the figures are arbitrary. The rules apply to any equipment rated 100 A or less.

For equipment with termination provisions for circuits rated 100 A or less or marked for 14 AWG through 1 AWG conductors, the NEC allows conductors to be used based on the following four conditions:

a. Conductors rated 60 °C (see Figure 3).
b. Conductors with higher temperature ratings, provided the ampacity is determined based on the 60 °C ampacity of the conductor (see Figure 4).
c. Conductors with higher temperature ratings, provided the equipment is listed and identified for use with such conductors (see Figure 5).
d. Conductors for specific motor applications (see Figure 6). This permission is specific to Design B, C, D, or E motors because those motors are temperature evaluated with conductors based on 75 °C ampacity according to NEMA MG-2 (Safety Standard for Construction and Guide for Selection, Installation, and Use of Electric Motors and Generators).

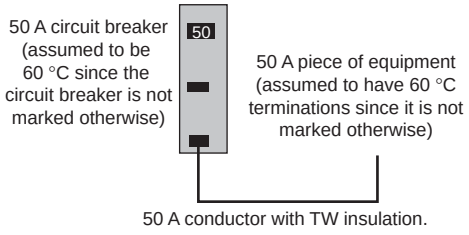


Figure 3: Conductors Rated 60 °C

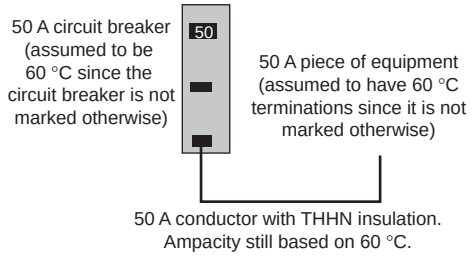


Figure 4: Conductors with Higher Temperature Ratings

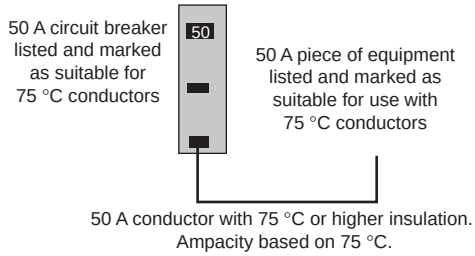


Figure 5: Conductors with Higher Temperature Ratings

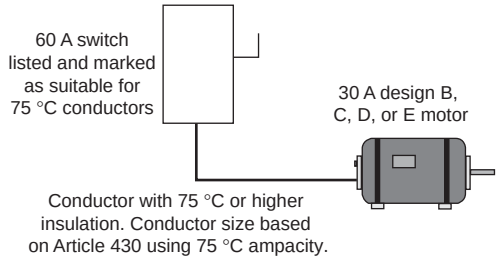


Figure 6: Conductors for Specific Motor Applications

Equipment Rated Above 100 A— NEC 110.14(C)(1)(b) items 1 and 2

For equipment with termination provisions for circuits rated above 100 A or marked for conductors larger than 1 AWG, the NEC 110.14(C)(1)(b) items 1 and 2 allow conductors to be used based on the following conditions:

a. Conductors rated 75 °C (see Figure 7).

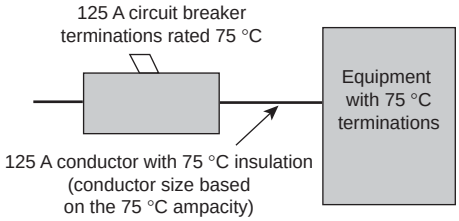


Figure 7: Conductors Rated 75 °C

b. Conductors with higher than 75 °C ratings provided the conductor ampacity does not exceed the 75 °C ampacity of the conductor size used (see Figure 8). This condition also permits the conductors to be used at ampacities higher than 75 °C if the equipment is listed and identified for the higher rating. However, for equipment rated 600 V and less, there is no listed equipment with termination ratings above 75 °C.

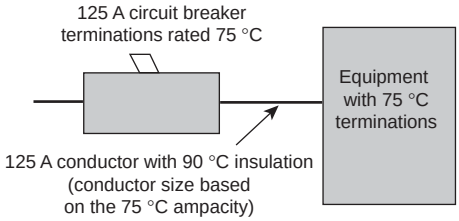


Figure 8: Conductors with Higher Temperature Ratings

The equipment termination ratings versus conductor insulation ratings are summarized in Table 2.

Table 2: Conductor Insulation Versus Equipment Termination Ratings

Termination Rating (°C)	Conductor Insulation Rating		
	60 °C	75 °C	90 °C
60	OK	OK (at 60 °C ampacity)	OK (at 60 °C ampacity)
75	No	OK (at 60 or 75 °C ampacity)	OK (at 60 or 75 °C ampacity)
60/75	OK	OK (at 60 or 75 °C ampacity)	OK (at 60 or 75 °C ampacity)
90	No	No	OK [1]

[1] The **equipment** must have a 90 °C rating to terminate 90 °C wire at its 90 °C ampacity. For listed equipment rated 600 V and less, the maximum rating is 75 °C.

CAUTION ON USING LUG RATINGS

When terminations are inside equipment such as panelboards, motor control centers, switchboards, enclosed circuit breakers, safety switches, etc., follow the temperature rating identified on the equipment labeling instead of the rating of the lug itself. Manufacturers commonly use 90 °C-rated lugs (i.e., marked AL9CU) on equipment rated only 60 °C or 75 °C. The use of the 90 °C-rated lug in this type of equipment does not allow the installer to use 90 °C wire at the 90 °C ampacity. The Underwriters Laboratories® General Information on Electrical Equipment Directory states the following about terminations: “A 75 °C or 90 °C temperature marking on a terminal (e.g., AL7, CU7AL, AL7CU or AL9, CU9AL, AL9CU) does not in itself indicate that a 75 °C or 90 °C insulated wire can be used unless the equipment in which the terminals are installed is marked for 75 °C or 90 °C.”

Review the labeling of all devices and equipment for installation guidelines and possible restrictions.

AVAILABLE EQUIPMENT TERMINATIONS

Remember that a conductor has two ends, and that the termination on each end must be considered when applying the sizing rules. For example, consider a conductor wired to a 75 °C termination on a circuit breaker at one end, and a 60 °C termination on a receptacle at the other end. This circuit must be wired with a conductor that has an insulation rating of at least 75 °C (due to the circuit breaker) and sized based on the ampacity of 60 °C (due to the receptacle).

For electrical equipment rated for 600 V and less, terminations are typically rated at 60 °C, 75 °C or 60/75 °C. No distribution or utilization equipment is listed and identified for the use of 90 °C wire at its 90 °C ampacity. This includes distribution equipment, wiring devices, transformers, motor control devices, and even utilization equipment such as HVAC, motors, and light fixtures. Installers and designers who have not realized this fact have equipment that does not comply with the National Electrical Code and that has been turned down by the electrical inspector.

In equipment rated over 600 V, the effect of the conductor as a heat sink is minimized, and ratings higher than 75 °C are available. NEC 110.40 recognizes that conductors with sizes based on the 90 °C ampacity can be used in installations over 600 V.

An example of how 90 °C wire might be used at its 90 °C ampacity is shown in Figure 9. Note that the conductor does not terminate directly in the distribution equipment, but in a terminal or tap box using 90 °C-rated terminations.

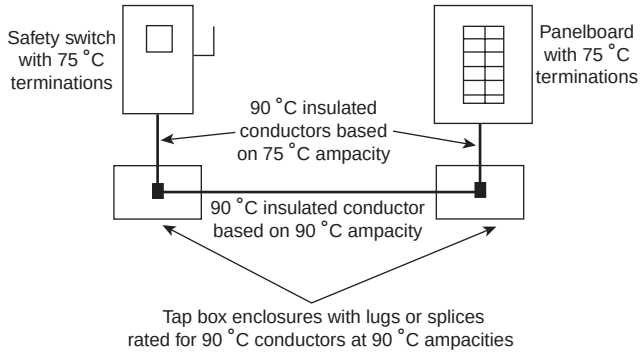


Figure 9: 90 °C Wire Used at 90 °C Ampacity

Frequently, manufacturers are asked when distribution equipment will be available with terminations that will permit 90 °C conductors at the 90 °C ampacity. This would require not only significant equipment redesign (to handle the additional heat), but also coordination of the downstream equipment where the other end of the conductor terminates. Significant changes in the product testing/listing standards also would have to occur.

A final note about equipment… some equipment requires the conductors that are terminated in the equipment to have an insulation rating of 90 °C, but an ampacity based on 75 °C or 60 °C. This type of equipment might include 100% rated circuit breakers, fluorescent lighting fixtures, etc., and is marked to indicate such a requirement. Check with the manufacturer of the equipment to see if you need to take into account any special considerations.

WHAT ABOUT HIGHER-RATED CONDUCTORS AND DERATING FACTORS?

One advantage to conductors with higher insulation ratings is noted when derating factors are applied. This advantage is noted in the last sentence of NEC 110.14(c): “Conductors with temperature ratings higher than specified for terminations shall be permitted to be used for ampacity adjustment, correction, or both.” Derating factors may be required because of the number of conductors in a conduit, higher ambient temperatures, or internal design requirements for a facility. By beginning the derating process at the ampacity of the conductor based on the higher insulation value, you may not be required to upsize the conductor to compensate for the derating.

Remember these points while studying the derating process example:

- The ampacity value determined after applying the derating factors must be equal to or less than the ampacity of the conductor based on the temperature limitations at its terminations.
- The derated ampacity becomes the allowable ampacity of the conductor, and the conductor must be protected against overcurrent in accordance with this allowable ampacity.

Example of the Derating Process

Assume that you have a 480Y/277 Vac, 3-phase, 4-wire feeder circuit to a panelboard supplying 200 A of noncontinuous fluorescent lighting load. Assume that the conductors will be in a 40 °C ambient temperature and the conductors originate and terminate in equipment with 75 °C terminations.

Additional information to consider from the NEC:

- Since the phase and neutral conductors all will be in the same conduit, consider the issue of conduit fill. NEC 310.15(b)(4)(c) states that the neutral must be considered to be a current-carrying conductor since a major portion of the load is a nonlinear load (electric discharge lighting).
- Based on this, four current-carrying conductors will be in the raceway. NEC 310.15(b)(2)(a) requires a 20% reduction in the conductor ampacity based on having four to six current-carrying conductors in the raceway.
- According to the ambient correction factors at the bottom of Table 310.16, an adjustment must be made of 0.88 for 75 °C and 0.91 for 90 °C.

Calculate, using a 75 °C conductor such as THWN:

300 kcmil copper has a 75 °C ampacity of 285 A.

Using the factors noted earlier: 285 A x 0.80 x 0.88 = 201 A

201 A is now the allowable ampacity of the 300 kcmil copper conductor for this circuit. Had the derating factors for conduit fill and ambient not been required, a 3/0 copper conductor would have met the needs for this application.

Calculate, using a 90 °C conductor such as THHN:

250 kcmil copper has a 90 °C ampacity of 290 A.

Using the factors noted earlier: 290 A x 0.80 x 0.91 = 211 A

211 A is less than the 75 °C ampacity of a 250 kcmil copper conductor (255 A), so the 211 A would now be the allowable ampacity of the 250 kcmil conductor. Had the calculation resulted in a number larger than the 75 °C ampacity, the actual 75 °C ampacity would have been used as the allowable ampacity of the conductor. This is critical since the terminations are rated at 75 °C. Note that the conductor size was reduced by one size (300 kcmil to 250 kcmil) and still accommodated all of the required derating factors for the circuit. This is the primary advantage of using 90 °C conductors.

Therefore, when using 90 °C wire for derating purposes, you can begin derating at the 90 °C ampacity. You must compare the result of the calculation to the ampacity of the conductor based on the termination rating (60 °C or 75 °C). The smaller of the two numbers then becomes the allowable ampacity of the conductor.

Use of Other Than Table 310.16

In the 2002 NEC, a change was made to add the last sentence to 110.14(C)(1) that states "Unless the equipment is listed and marked otherwise, conductor ampacities used in determining equipment termination provisions shall be based on Table 310.16 as appropriately modified by 310.15(B)(1) through (6)." This sentence makes it clear that the ampacities of conductors at terminations are to be based on Table 310.16 and not the other tables in Article 310. Other tables may be applicable for the conductors in a specific environment, but in all cases the ampacity at the termination must be based on Table 310.16. For instance, a single conductor installed in free-air may have its ampacity determined by Table 310.17. Examples of those circumstances where this may be useful include ambient derating and installation in a cable tray (see Article 392). However, at the point where the conductor is terminated in equipment, the ampacities of Table 310.16 will govern. This may require that a larger conductor be used or that the conductor size changed prior to entering the equipment.

Number of Conductors Per Terminal

The NEC contains some key references regarding how many conductors can be terminated in a single terminal. NEC 110.14(A) has a blanket statement requiring that terminals for more than one conductor shall be so identified. This would mean that the terminal (or terminal bar) would have to be identified to accept more than one conductor. For equipment that contains a terminal or terminal bar, this identification is generally found on the wiring diagram or some other label on or inside the product.

In addition, the 2002 NEC has added clarifying language regarding terminals for grounded conductors in panelboards. NEC 408.21 makes it clear that a terminal for a grounded conductor in a panelboard is acceptable for only one conductor. This NEC requirement correlates with a long-standing rule contained in UL 67 – Standard for Safety for Panelboards. One common mistake is for installers to misinterpret the marking found on many panelboards that allows multiple equipment grounding conductors in a single terminal to apply to grounded conductors as well. This NEC language will help installers avoid this error at the outset rather than finding out from the electrical inspector at final installation. The added language also makes it clear that a terminal identified for more than one conductor can still be used for grounded conductors installed in parallel.

SUMMARY

Proper termination of conductors is a critical part of having a safe electrical installation. Assigning the ampacity of a conductor is impacted by not only the physical characteristics of the conductor, but the connected equipment as well. Closely adhering to the NEC rules will not only avoid rejected installations from inspectors, but will help to avoid having problems with the terminations in the future.

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