STANDARDS WATCH

BREAKING CONVENTION: INDUSTRY USE OF PORTABLE CORDS AND CABLES

by Ken Vannice

The entertainment industry often uses unconventional methods to practice its craft. The same is true for the electrical portable cords and cables that it uses. For example, standard practice for feeder cables was to use welding cable and connectors, until the 1984 Olympics. During the Olympics an enterprising company asked the City of Los Angeles if it could use welding cable and connectors for Olympic venues. The city's post-Olympic response, "No!" gave birth to the USITT Engineering Commission's major launch into the world of the National Electrical Code (NEC).

The entertainment articles in the NEC have been specifically written to provide a reasonable level of safety, while allowing the industry the freedom needed to practice its craft. With privilege comes responsibility. If the industry does not use its privilege responsibly it will lose the privilege. In order to act responsibly, the industry needs to understand the requirements and their underlying principles. This article delves into the underlying principles of the special use of portable cords and cables in the entertainment industry.

Portable electrical cords and cables are flexible copper conductors with flexible insulation. They also include a flexible outside jacket making them suitable for use lying out in the open rather than installed in walls or conduits. The purpose of the insulation is to keep the conductors from contacting each other or other things that might produce a short circuit. Obviously, if the insulation gets hot enough to melt or burn, it will not be doing its job very long. Heat can also degrade the insulation until, over time, it fails to do its job. The insulation and the outer jacket traps the heat generated by the conductors resulting in the assembly getting hot and possibly failing. The inter-heating of the conductors within the jacket creates additional heating effects. ("Cords" and "cables" are terms with specific meanings in the National Electrical Code. There, small, multi-conductor cables are called "cords.")

The Basics

Before we delve into the special entertainment use of portable cords and cables let's look at some basic concepts of the ampacity tables found in the National Electrical Code. Ampacity is "the current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating" (not unduly damaging the insulation). Ampacity is what allows cords and cables to have different ampere ratings under different conditions. As more current is allowed to flow in a wire it gets hotter. Better insulation is required to withstand greater heat. Better insulation is used to allow a wire to carry more current, or it is used to allow a wire to work in an environment with a higher ambient temperature. One sometimes sees the phrase "90-degree C rated wire used at 75-degree C ampacity." This means that wire with better insulation is being used as though it were wire with a lower temperature rating because the higher temperature rating of the insulation is needed to handle a higher ambient temperature in the environment and not to increase the ampacity.

Article 240 of the NEC requires that cords and cables be protected with overcurrent devices in accordance with the ampacity tables and their corresponding notes. The only exception in Article 240 is for extension cords where 16AWG and larger cords are permitted to be protected by a 20A overcurrent device. In the entertainment articles, there are "tap" rules permitting the overcurrent device to be up to 400% greater under certain conditions. This does *not* mean that 16AWG extension cord can be loaded to 20A or that 4/0AWG cable can be loaded to 1600A. Article 240 also requires overcurrent protection for equipment including connectors.

Single-Conductor Cables

In the aftermath of the 1984 Olympics the NEC Committee set out to find a way to include single-conductor feeder cable in Article 400 of the NEC. In order to do this an ampacity table had to be created to cover these new uses. The code panel for Article 400 was adamant about retaining the existing table for what it considered residential and commercial products. If ampacities for larger cables and single-conductor cables were to be added they would have to be added in a new, industrial grade, table. The committee knew it wanted to attain the ampacities the entertainment industry had been using safely and successfully for years. So, with the help of UL, the committee

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found some acceptable data. This data became Table 400.5(B) allowing the traditional rating of 400A for 4/0AWG cable. Significant to our single-conductor feeder cable issue is column D of that table. Cable rated 90-degree C is commonly available and gives us our 400A capability.

If one compares the D columns of Table 400.5(B) to the copper columns of Table 310.17 one will find a similarity. Note that Table 310.17 covers single-conductor cables in free air, for example, hanging far apart on power poles. These ampacities are only valid when each cable is able to dissipate heat in free air or a close approximation of free air. If the cables are lying on a surface, the surface must provide a heat sink comparable to free air. Blacktop in the direct sun is definitely not such a heat sink but a heat source. Obviously, if the cables are piled on top of each other they are not in free air. Where they are allowed to contact each other for short distances, wicking the heat out to where they are not touching is relied on to keep the temperature down. This suggests that banded single-conductor cables must be splayed out between the bands so that the cables don't touch each other and the heat can be dissipated. A better idea for banded cables would be to use the lower ampacities in columns E or F as appropriate.

Terminations

Proper selection and use of the cable isn't the only requirement. The cable must be terminated properly. If it is connected to terminals or lugs rated "copper only" it can be used at its 90-degree C ampacity rating as all copper lugs are normally rated 90-degree C. If aluminum/copper terminals are used at the 90-degree C ampacity rating they must be specially marked AL9CU. Aluminum/copper lugs are normally rated at 60-degree C ampacity and may be marked AL7CU for use at 75-degree C ampacity.

Terminals and lugs that are integral parts of equipment have further restrictions. Circuit breakers are normally marked for use with 60-degree C ampacity wire with some marked for 75-degree C ampacity wire, and almost none for 90-degree C. This means that the 4/0AWG cable must not be connected directly to a circuit breaker and used at 400A. Most connectors (plugs and receptacles) are normally rated for the 60-degree C wire found in Table 400.5(A) of the NEC. The exception is the cam-connector, which is specifically marked for use at 90-degree C ampacity. Does this mean that it is okay to use banded single-conductor cable in a stage pin connector at the 90-degree C single-conductor ampacity? No, the pin connector has terminals rated for only 60-degree C multi-conductor ampacity because it has no special markings. Furthermore, the pin connector's strain-relief most likely has not been evaluated for multiple single-conductor cables.

Borderlight Cable

Another special use of portable cords and cables in the entertainment industry is for borderlight cable. Multiconductor cable is used between grid junction boxes and borderlights or connector strips. A typical run is usually in the range of 20 to 36 conductors. The ampacity of multiconductor cable is found in Article 400 of the National Electrical Code. Table 400.5(A) gives values for ampacity as discussed in Section 400.5. The first paragraph of Section 400.5 contains the derating requirements to be applied to the three-conductor values in Table 400.5(A)

Size (AWG)	Temperature rating of cords and cables 75°C (167°F)	90°C (194°F)	Maximum rating of overcurrent device
14	24	28	15
12	32	35	20
10	41	47	25
8	57	65	35
6	77	87	45
4	101	114	60
2	133	152	80

Table 520.44 gives the ampacity at an ambient temperature of 30°C of listed extra-hard-usage cords and cables with temperature ratings of 75°C and 90°C, which are commonly used for borderlight cables. The table assumes that only three conductors carry power. When more conductors carry power, the following derating table in Table 520.44 may be used, but only if the load diversity factor is at least 50%.

Number of conductors	Percent of ampacity
4-6	80
7-24	70
25-42	60
43 and above	50

Table 400.5. If the load diversity factor is more than 50% there will be more heating in the cable, so the derating factors shown below must be used.

Number of conductors	Percent of ampacity
4-6	80
7-9	70
10-20	50
21-30	45
31-40	40
41 and above	35

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when there are more than three current-carrying conductors. For 20 current-carrying conductors (the grounding conductors are not supposed to be carrying current) the derating value is 50%, and 40% for 36 conductors. Applying these percentages to the values in Column A of Table 400.5(A) increases the normal 12AWG cable for 20A to 6AWG for 20 conductors and 4AWG for 36 conductors. Borderlight cables containing 36 conductors of 4AWG do not rig very well, and it seems unnecessary to require such cable when the entertainment industry has been using cable with smaller conductors successfully for many years.

In about 1992, the USITT NEC Committee, with the help of Underwriters Laboratories, proposed the basis for what became Section 520.44(B), Cords and Cables for Border Lights, which includes Table 520.44. While it is not stated, Table 400.5(A) in Article 400 includes cords and cables with a temperature rating of 60-degree C. Today it is obvious that cords and cables of this type are also available with ratings of 75-degree C, 90-degree C and even 105-degree C. Because of termination issues it was necessary to leave Table 400.5(A) alone and introduce the other temperature ratings in Table 520.44. Table 520.44 has been constructed so as to allow the ampacities for the higher temperature ratings to be used *only* in relation to the derating requirements and *not* for additional ampacity. This is accomplished because the values in the right-hand column of Table 520.44 are the same as Column A of Table 400.5(A). Since 90-degree C-rated borderlight cable is readily available, the 90-degree C values can be used when applying the derating percentages of Section 400.5. Doing so reduces the examples indicated above from 6AWG and 4AWG to 10AWG and 8AWG respectively.

The cable situation is now better, but a borderlight cable of thirty-six 8AWG conductors is still unwieldy, so Table 520.44 includes another derating table, which is much more friendly to the borderlight situation at hand. If we apply these new percentages to our examples, our 10AWG and 8 AWG cable both reduce to 12AWG. Cables containing 36 conductors of 12AWG are much easier to rig, and have proven to work when powering borderlights.

We have just found a way to reduce cost and weight of our borderlight cables. What did we give up in the process? When applying the table, we need to remember this special case is for cable that hangs in free air from the grid junction box to the borderlight. Should it be bundled together or laid on top of itself in layers? No! Exploring the situation further, we see that Section 520.44(B)(2) informs us that this cable must not be in direct contact with equipment containing heat-producing elements. This infers that the cable enters borderlights via a separate junction box and that it is not laid on top of borderlights or other luminaires attached to the connector strip. Tests conducted in preparation for the NEC proposal indicated that this cable needs to be around three feet above these luminaires.

Applying the derating percentages found in Table 520.44 in lieu of those in Section 400.5 creates some additional cautions. Note that in the paragraph preceding the derating percentages in Table 520.44 it states that the derating is applicable only when there is a diversity factor of 50% at a minimum. This means that the circuits are always dimmed to 50%, or that only 50% of the circuits are on at any one time, or some combination that reduces the heating effect by one-half or more. This condition is probably quite likely for a stage show with traditionally dimmed incandescent luminaires. If moving lights with continuously operating arc lamps or borderlights used as rehearsal or lecture lights are involved, the 50% diversity requirement will probably not be met, and the derating percentages in Section 400.5 should be used instead of those in Table 520.44.

Rock-and-Roll Snakes

A special use of borderlight cable is for rock-and-roll snakes: multi-conductor cable with multipole connectors used in branch circuits. This use involves additional consideration. Mentioned previously is the fact that the ampacities listed in Table 400.5(A) are based on cable with a 60-degree C rating. For that reason, common connectors are usually only rated for use at this 60-degree C rating. When Table 520.44 is applied, smaller gauge 75-degree C and 90-degree C-rated cable is allowed. For a given load, this smaller cable runs hotter and could cause under-rated connector terminals on rock-and-roll snakes to fail. The higher temperature rated cables do not have this problem under their normal use in other applications, as they are usually terminated on both ends in terminal blocks.

A Final Note

The entertainment industry has been given a lot of freedom with modern codes and standards to practice its craft. In the process, electrical equipment has the potential to be used to its limits. If the industry pays attention to these limits and the equipment's proper use, current practices will be allowed to continue. If failures begin to occur because equipment has been pushed too far and the limits ignored, the requirements will become more restrictive and creativity will be limited.

Disclaimer

This article contains opinions based on the National Electrical Code. Official interpretations of the NEC can only be made by the NFPA and the local authority having jurisdiction.

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