



VERTIV WHITE PAPER

Avoid the Meltdown:

Your rPDU Is High Temperature Rated, but Are the Components?

Over the past few years the typical ambient operating temperature in the data center environment has increased. Operating a data center at a raised temperature is intended to decrease cooling costs and increase power efficiency. A data center will achieve an estimated 4% operational savings from cooling expense for every 1°C increase in operating temperature¹. In response to the increased operational temperature requirements for data centers, many manufacturers of rack power distribution units (rPDUs) have begun to increase the ambient operating temperature limits on their products to 60°C.

Operating in a higher temperature environment places additional stresses on rPDUs. Manufacturers must account for the higher operating temperature environment when selecting power path components, when designing monitoring and control circuit boards and when testing the rPDU for reliability and safety. To properly rate an rPDU for the ambient operating temperature of 60°C, all parts of the rPDU must be able to safely operate at the higher temperature. Two significant product safety concerns that are often overlooked when rPDUs are rated for maximum nameplate operation in a 60°C environment are the ampacity of the input cord and regulatory limitations on the maximum receptacle pin temperature. It is imperative that rPDUs—including ampacity of the cord and maximum receptacle pin temperature—have been properly rated and tested to safely operate in higher temperature environments.

A DATA CENTER WILL ACHIEVE AN ESTIMATED 4% OPERATIONAL SAVINGS FROM COOLING EXPENSE FOR EVERY 1°C INCREASE IN OPERATING TEMPERATURE¹.

Cord Size Requirements

The correct selection of input cord type and size is critical to the overall safety of an rPDU product throughout its functional life. This is especially important in an rPDU rated for use at a high ambient temperature because the current carrying capacity of the cord decreases as the ambient temperature increases. The correct cord size is based on a product's input current rating, the number of current carrying conductors in the cord and the product's rated ambient operating temperature range. In the United States, the product safety standard for rPDUs, UL 60950-1, refers to tables in the National Electric Code (NEC) for the correct sizing of power cords. The impact of ambient temperature on the rPDU cord size requirements is often overlooked on high temperature rPDU products.

To illustrate the impact of ambient temperature on cord size, consider the example of an rPDU with the following input ratings: 24 Amps, 230/400 VAC 3~ WYE, 50/60 Hz. The tables in the NEC provide the minimum conductor size, based on conductor ampacity, for a three-phase product with three current carrying conductors. The neutral is generally not considered a current carrying conductor when sizing a cord for an rPDU because the neutral only carries unbalanced current from the line conductors in the cord. The tables in the NEC also provide a de-rating factor for ampacity that must be applied when cords are used in environments with ambient temperature ratings above 30°C. Using the relevant values from these tables the minimum acceptable cord size for an rPDU can be calculated based on the rPDU's rated input current and maximum allowable operating ambient temperature. The results of this analysis and the required cord sizes are presented in Table 1.

¹Miller, R. (2008). Google: Raise Your Data Center Temperature. Data Center Knowledge. Retrieved from: <http://www.datacenterknowledge.com/archives/2008/10/14/google-raise-your-data-center-temperature/>.

Input Current Rating (Amps per Phase)	Temperature Rating (°C)	Nominal Cord Size Used in Industry, SO Type	Ampacity of Nominal Required Cord Size	De-rating Factor	Ampacity of Nominal Required Cord Size After De-Rating	Actual Required Cord Size with Temperature De-Rating
24	30	10 AWG	25	1	25	10 AWG
24	45	10 AWG	25	0.87	21.75	8 AWG
24	60	10 AWG	25	0.71	17.75	8 AWG
24	65	10 AWG	25	0.58	14.5	6 AWG

Table 1: Required Cord Size for 24A, 230/400 VAC 3~ WYE, 50/60 Hz rPDU

As Table 1 shows, the typical 24 Amp rPDUs on the market today will have a 10 AWG input cord regardless of the maximum ambient temperature rating of the rPDU. The 10 AWG cord is sized appropriately for rPDUs used at 30°C, however it is significantly undersized for a rPDU used in a 60°C environment. The 10 AWG input cord on a 24 Amp rPDU is only rated to carry 17.75 Amps continuously in a 60°C environment. Using a cord above its temperature adjusted ampacity rating as shown in the NEC may result in an electrical hazard due to the failure of cord insulation.

USING A CORD ABOVE ITS TEMPERATURE ADJUSTED AMPACITY RATING AS SHOWN IN THE NEC MAY RESULT IN AN ELECTRICAL HAZARD DUE TO THE FAILURE OF CORD INSULATION.

Applied Knowledge for Consumers

Always consult local regulations, but to determine if a cord has been properly sized for an rPDU based on the products temperature rating, refer to Article 400.5 of the NEC. Alternatively, ask the rPDU manufacturer to provide evidence showing that the rPDU cord has been appropriately sized including considering de-rating factors for number of current carrying conductors and maximum rated ambient operating temperature.

²Although the table indicates that an 8 AWG cord is required, standard practice for most rPDU manufacturers is to use a 10 AWG / 5 Conductor cord for 45 C ratings. The slight discrepancy between the ampacity rating from the NEC tables and the cord chosen may be handled by measuring the maximum temperature of the cord during the NRTL heating test and determining that the cord will not exceed its insulation temperature rating at maximum normal load. It is unlikely that this type of testing will produce compliant results at higher ambient temperature.

Cord Size Requirements

European and Other Regions

In regions where the UL 60950-1 safety standard is not applicable, the internationally harmonized IEC 60950-1 standard or the European Norm EN 60950-1 are typically used to ensure safe construction and operation of rPDU products. Both IEC 60950-1 and EN 60950-1 require that all components, including the input cord, are used in compliance with the safety aspects of any relevant IEC component standards. Rack PDUs intended for the global market are typically built with heavy duty rubber insulated (H07RN-F) cable. To comply with the relevant safety standard for this cable, the cable must be used in accordance with both EN 50525-2-21 Electric Cables – Low voltage energy cables of rated voltages up to and including 450/750 V and HD 516 S2 Guide to use of low voltage harmonized cables.

Many rPDU manufacturers rely on “Table 3B – Size of Conductors” from IEC 60950-1 or EN 60950-1 to assist in determining the input cable size required. Utilizing Table 3B to choose the appropriate cable size for rPDUs using H07RN-F may lead to the use of undersized cable for two reasons. First, the ampacities listed in Table 3B are intended for single phase cable only and do not contain any derating factors that are required by HD 516 for three phase cable. Second, the ampacities listed in Table 3B are intended for cables that are used in 30 °C operating environment and do not contain any temperature based de-rating factors required by HD 516. To be sure the cable size has been selected correctly for the application, manufacturers should use the ampacity tables and ambient operating temperature de-rating factors supplied in the HD 516 document.

The table below shows the ampacity of a frequently selected H07RN-F cable size for a 32 Amp, three-phase rPDU vs ambient operating temperature. A de-rating factor for the three-phase application.

Input Current Rating (Amps per Phase)	Temperature Rating (°C)	Nominal Cord Size Used in Industry, H07RN-F Cable	Ampacity of Nominal Required Cord Size	De-rating Factor	Ampacity of Nominal Required Cord Size After De-Rating*	Actual Required Cord Size with Temperature De-Rating (100% rPDU Load)
32	30	4 mm ²	38	1	38	4 mm ²
32	45	4 mm ²	38	0.71	26.98	6 mm ²
32	50	4 mm ²	38	0.58	22.04	10 mm ²
32	55	4 mm ²	38	0.41	15.58	16 mm ²

*based on 85°C conductor operating temperature

Table 2: Required Cord Size for 32A, 3 Phase rPDU

The above table reflects the size vs temperature rating of standard H07RN-F cable only. Some rPDUs utilize PVC or other cable such as LSOH, these may have alternate maximum Current carrying capacity and temperature de-rating factors that differ from the above table. Similarly, rPDUs constructed with H07RN-F cable rated for high temperature operation may have current carrying capacities different from the above table.

²Although the table indicates that an 8 AWG cord is required, standard practice for most rPDU manufacturers is to use a 10 AWG / 5 Conductor cord for 45 C ratings. The slight discrepancy between the ampacity rating from the NEC tables and the cord chosen may be handled by measuring the maximum temperature of the cord during the NRTL heating test and determining that the cord will not exceed its insulation temperature rating at maximum normal load. It is unlikely that this type of testing will produce compliant results at higher ambient temperature.

Receptacle Maximum Temperature Limits

Most high temperature rPDUs on the market today are constructed with C13 and C19 style IEC 60320-2-2 appliance outlets. These outlets were designed for household or similar use and were intended to be used in operating environments with a normal ambient temperature of 25°C, occasionally approaching 35°C. The IEC 60320-2-2 standard establishes a 70°C maximum pin temperature limit for the C13 and C19 outlets. Consequently, the receptacle temperature measured in the rPDU cannot exceed 70°C for the rPDU to meet UL 60950-1 requirements. During Nationally Recognized Testing Laboratory (NRTL) safety testing of the rPDU product, the receptacle temperature is typically measured on a single receptacle's plastic housing, as close to a conductive pin as possible. The measurement is made with both the rPDU and receptacle loaded under maximum normal load conditions while operating at the maximum ambient temperature rating. Maximum normal load is defined as the rPDU loaded to its maximum nameplate input current rating with the receptacle under test also loaded to the maximum receptacle output current rating. To be compliant with UL 60950-1 requirements, the receptacle temperature is not allowed to exceed 70°C during this test. Thus, the maximum temperature rise recorded on either a C13 or C19 receptacle must be less than 10°C during this test for the rPDU to meet UL 60950-1 requirements.

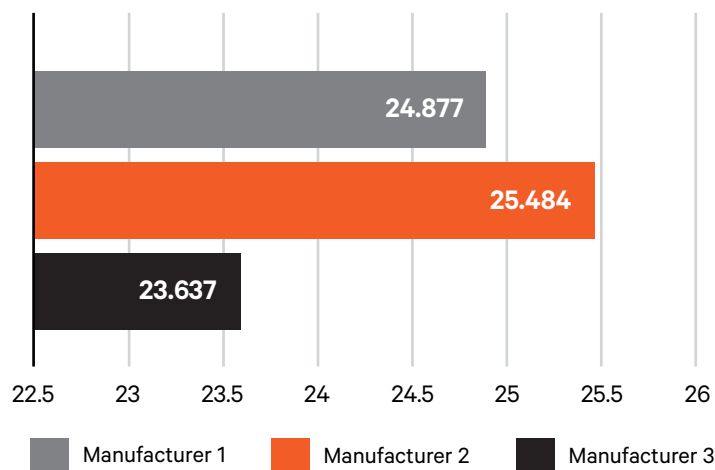
Three separate manufacturer's test samples were subjected to the test condition described above. All three samples were 32 Amp, 230/400 VAC 3~ WYE, 50/60 Hz rPDUs. All samples were loaded to 32 Amps per phase, with 16 Amps on each C19. The results of this testing are presented in Figure 1 on the following page.

Based on the requirements described above, a 60°C rated rPDU must have a receptacle temperature rise of 10°C or less to be compliant with safety requirements. Figure 1 demonstrates that all three rPDU products tested would not meet the receptacle temperature limits in an ambient temperature of 60°C. Using an IEC 60320-2-2 appliance coupler outside of its maximum temperature limit may result in a hazardous condition by causing damage to the receptacle itself or by causing damage to any connected cords.

Applied Knowledge for Consumers

To determine if the receptacle pin temperature has been properly accounted for in the rPDU's temperature ratings, ask the manufacturer if any de-rating of receptacle output current is required for high temperature operations. If no de-rating is required, ask the manufacturer to provide evidence that both the rPDU and receptacle were fully loaded during NRTL heating tests.

Maximum Normal Load Temperature Rise on C19 Receptacle



Conclusion

The discussion and test results show two significant product safety concerns—the ampacity of the cord and maximum receptacle pin temperature—are often overlooked when rPDUs are rated for maximum nameplate operation in a 60°C environment.

These concerns can be adequately addressed if manufacturers change their approach to high temperature rPDU operational ratings. Manufacturer's will be able to properly account for cord ampacity and receptacle temperature limitations by offering a two-tiered rating system. A two-tiered rating system will allow rPDU products to be rated for maximum nameplate input current and per receptacle output current operation at ambient temperatures up to 45°C. Additionally, a two-tiered rating system will allow the rPDU to be rated for 50% of maximum nameplate and 50% of maximum receptacle output current operation at ambient temperature up to 60°C. The rPDU will be capable of operating at full nameplate ratings at 60°C for short time intervals such as during a failover event where a single feed in a redundant power system is lost. This two-tiered rating system will ensure that the cords and receptacle components within the rPDU are operated well within their safety limits.



Vertiv.com | Vertiv Headquarters, 1050 Dearborn Drive, Columbus, OH, 43085, USA

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