Ferrules: Your Best Insurance Against Costly Connection Failure

Executive Summary

Thanks to its superior flexibility, longer flex life*, and resistance to vibration, insulated stranded wire is the ideal choice for most panels. From both a physical and electrical perspective, however, bare stranded wire is a poor choice for connections. Stripped of its insulation, stranded wire quickly loses the coherence that provides its strength and resiliency. Once it begins to unravel, it is subject to breakage and corrosion that can produce overheating, short circuits, and connection failure, as well as cause serious safety issues.

Ferrules can rectify this situation by giving stranded wire the qualities of solid wire where it is needed most, at the point of connection. Ferrules significantly simplify installation, improve safety, and diminish the risk of costly panel failure. This white paper highlights the advantages of ferrules for electrical connections and includes guidelines for their selection and purchase.

There's Strength in Numbers

Stranded wire is the wire of choice for most electrical applications. Due to its superior flexibility and longer flex life, it offers more routing options than solid wire. Stranded wire is also more durable. It stands up to vibration and sudden movement that can cause rigid solid wire to snap.

Stranded wire gains its flexibility from the way the bundles of wire in the strands are woven together. The integrity of the stranded bundles is further reinforced by the jacket of insulating material that surrounds them. The moment the insulation is stripped from the wire-end, however, its strength is transformed into a source of weakness as wire bundles unravel and individual strands are exposed. In the process, the potential for short circuits and failed connections rises dramatically. Identifying shorts is a time-consuming process. In case of a typical panel, this could mean testing hundreds of connections, causing extensive downtime.

A Bare Connection Yields Bare Bones Results

With stranded wire, the old adage applies: the whole is indeed greater than the sum of its parts. The reverse, unfortunately, is also true. Once the insulation is removed and stranded wire begins to unravel, ease of installation is sacrificed as well as the long-term electrical performance, durability and safety of the connection.

Installation

The problems with bare stranded wire connections begin the moment the stripping tool is put down and an attempt is made to place the bare end of the stranded wire into the terminal compartment. If care is not taken, the wire will begin to splay, making installation painstaking and time-consuming.

If the unraveling wire is successfully inserted into the terminal block, it is unlikely that the full electrical efficiency of the connection will be realized. If the strands have fanned out, not all of them will make contact with the connector and be available to conduct current. Furthermore, the individual strands, once isolated, can break easily. This is particularly an issue when stranded wires are used with spring clamp connectors.

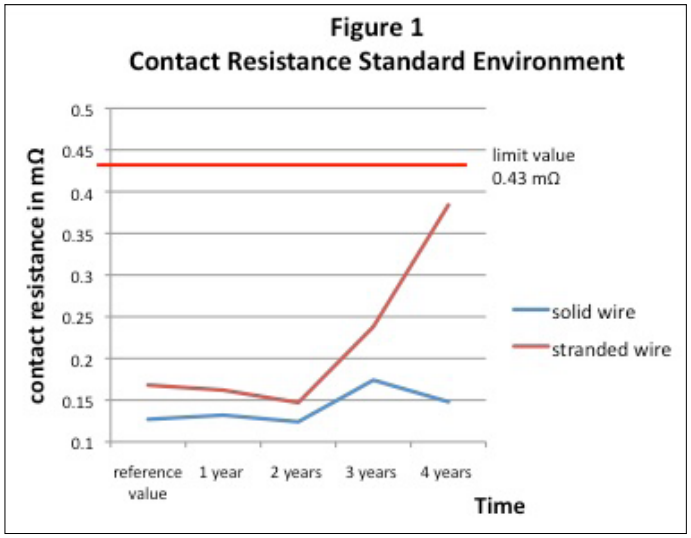
* Flex life refers to a cable or wire's resistance to stress, from repeat bending.

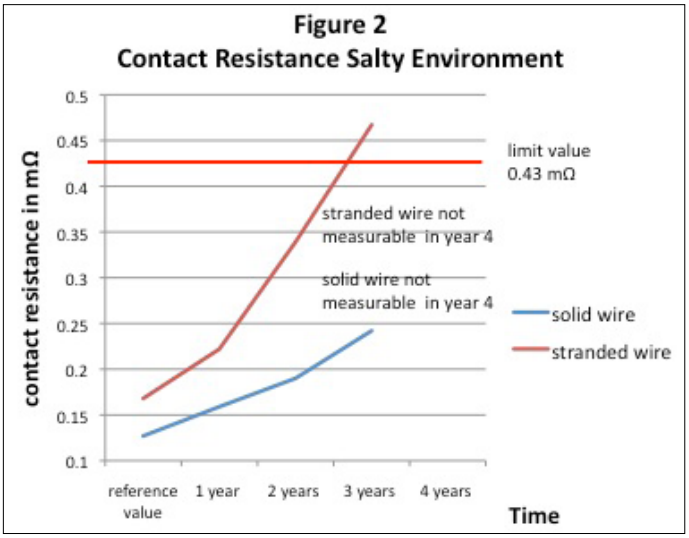
Long-Term Electrical Performance

Stripping the insulation and exposing the stranded wire to air also undermines the long-term electrical performance of the connection. Weidmuller technicians conducted a series of test using a Weidmuller SAK 4 screw terminal and a Weidmuller AWG 12 ferrule in a climate-controlled cabinet. Over time, corrosion of the unprotected stranded wire produces an increase in contact resistance, as **Figure 1** shows.

As the contact resistance rises, the temperature inside the connection increases, leading to higher current flow. Above 0.43 mΩ, this can lead to losses of insulation, short circuits, and burning within the panel.

In a salty environment, contact resistance of stranded wire approaches its limit even more quickly, as **Figure 2** demonstrates.





Uninsulated stranded wire extending out of the terminal block can also increase leakage and creepage distances. Excessive leakage and creepage can heat up the connection and cause short circuits.

Durability

Under normal conditions, stranded wire provides superior vibration resistance compared to solid wire, based on way the strands are woven together. When stranded wire is stripped, the exposed bundles of strands lose their coherence and begin to separate. When subject to vibration, these individual strands are susceptible to loosening the connection or breaking. In addition, strands can easily break when bent or stressed. In either case, the result is decreased current flow and, eventually, failed connections.

Safety

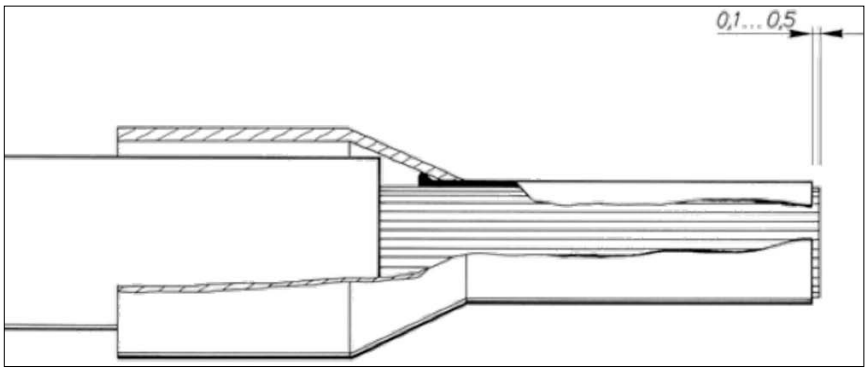
Taken together, using bare stranded wires at the point of connection not only degrades system performance, but also poses significant safety risks. Higher temperatures, short-circuits, and, in some cases, arc flashes can result, endangering personnel as well as equipment.

[1]The results of the "Standard Environment" test are shown in Figures 1 and 3. They were performed using average temperature and humidity in Detmold, Germany. The results of the "Salty Environment" tests are shown in Figures 2 and 4. They were performed using the average temperature and humidity of the Sylt Island of the North Sea.

Ferrules—Making a Solid Connection

During the 1960s, engineers realized that one way to overcome the deficiencies of bare stranded wire at the point of connection was to give the exposed section the virtues of solid wire. They did this by encasing it in a tin-plated soft-electrolyte copper (E-CU-57) ferrule, which is crimped in place.

Over the years, ferrule technology has been improved. In the 1970s, ferrules were introduced with a plastic conical cable entry, providing added safety and durability. In the 1990s, twin ferrules, allowing for the simultaneous insertion of two wire-ends, were invented, and DIN 46228 was adopted to standardize the sizes, dimensions, and testing of ferrules.



As shown in the illustration, the conductor insulation must be pushed into the plastic collar, and the conductor should completely fill the ferrule sleeve. Depending on cross-section, the conductor should protrude as much as 0.5 mm from the ferrule sleeve.

An Efficient Use of Time and Resources

Ferrules are required in Europe for CE certification—and it is easy to understand why. They enable users to take advantage of the features of stranded wire without the problems caused by a bare-wire connection. The few seconds required to apply a ferrule to the wire-end are more than made up by the ease of insertion. Because the ferrule completely encases the stranded wire, the quality of the connection is far superior, and there is no possibility that the wire can break, even when used with tension clamps. No matter how many times the wire is removed and reinserted, the ferrule retains its shape and integrity.

The long-term electrical performance is also higher because ferrules, applied with the proper crimping tool, form a gas-tight* connection shielding the wire from corrosion even in a salty environment. Analysis shows that stranded wire with ferrules demonstrate resistance over time that is similar to solid wire, as **Figures 3 and 4** illustrate.

Figure 3
Contact Resistance Standard Environment

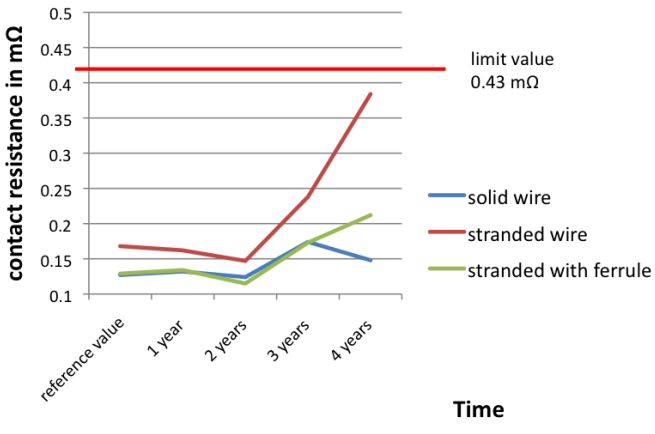
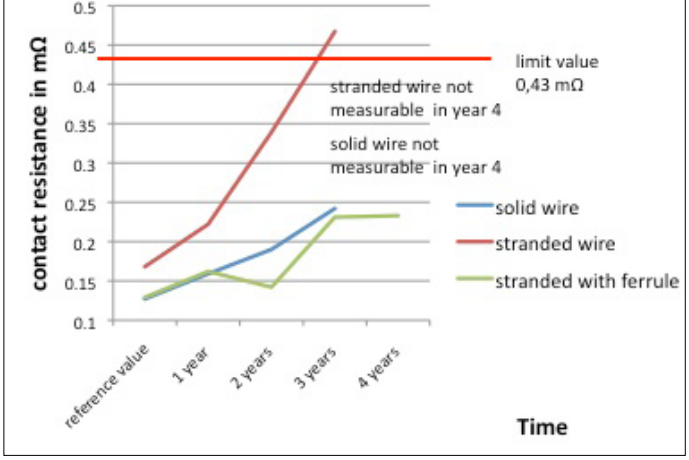


Figure 4
Contact Resistance Salty Environment



* "Gas tight" refers to the ability of air or gasses to permeate a connection

In addition, ferrules with plastic collars reduce leakage and creepage values as well as gas intrusion. This is particularly important in components like PLCs, where connection density is important. Stranded wire-ends protected by ferrules are also much more resistant to vibration and breakage at the connection.

In effect, ferrules produce a much more efficient and durable connection than can be attained with bare stranded wire—which results in significant savings over the life of the system. The standard size ferrule for a 16 AWG wire typically costs $0.05. If there are 1,000 connections in a panel, the total cost is $50. That is a fraction of what downtime, testing, repair, and replacement costs can run in the event of a short circuit.

Most important, ferrules also provide a critical margin of safety for operators, reducing the potential for shorts and arc flashes.

Sourcing Ferrules Wisely

Although ferrules might seem like a commodity product, they are not. When you source ferrules, it is critical to select a supplier whose ferrules go beyond the immediate advantage of simplified installation to provide an efficient, durable, and safe connection over the long term.

Accordingly, when specifying or purchasing ferrules, keep the following guidelines in mind:

- Choose a manufacturer who adheres to the DIN 46228 standard. This standard describes the allowable dimensions and tolerances of the plastic collar and metal sleeve, ensuring the quality of the connection. The crimped connection is subject to a pull-out force test calibrated to the cross section of the wire. In addition, it provides a uniform color-coding system for ferrules with plastic collars, with a specific color for every cable cross section. Thanks to this system, users can immediately recognize different cables, minimizing confusion and increasing operational safety.
- Select a manufacturer whose ferrules have UL approval. This is particularly important when using ferrules in UL-certified panels. All UL 508 panels must use UL-listed components.
- Choose a manufacturer who offers crimping tools and contacts that are designed to work together, a recommendation contained in UL 508 and DIN EN 60352-2. Equally important, select a manufacturer who has subjected its crimping tools, ferrules and connection systems to rigorous testing. These tests should include gas intrusion, vibration, bending, and long-term connectivity testing, as well as pull-out tests for screw and tension clamps and for innovative connection technology like push-in connectors.
- Make your purchases from a manufacturer who offers a broad range of crimping shapes (including trapezoidal, trapezoidal indent, square, and hexagonal shapes), ferrules (with and without plastic collars as well as twin ferrules), terminal blocks, and other devices so that you can return to the same supplier for all your connection needs and maintain a consistent quality standard.

Standards-Based Crimping in an Unequaled Range of Shapes and Sizes

Our goal at Weidmuller is to support our customers and partners around the world with products, solutions and services that truly serve their needs. As a result, we have taken pains to ensure that our crimped connections meet DIN and UL standards, and we have committed ourselves to producing ferrules in a wide range of sizes, color codes, and configurations, as well as crimping tools that produce an unsurpassed assortment of shapes.

Meeting Industry Standards

At Weidmuller, our approach to ferrules and crimping tools is straightforward: by adhering to industry standards, we add value for our customers. For instance, we subject ferrules crimped with Weidmuller tools to pull-out force tests, as required by DIN 46228.

During the test, we pass the crimped conductor through a perforated template firmly clamped to a pull-out force testing machine. We then apply a steady tensile force for one minute. The pull-out forces that Weidmuller crimped ferrules withstand are enumerated in DIN EN 60999 part 1:

DIN Pull-Out Force Testing

Cross section sq. mm	0.2	0.34	0.5	0.75	1.0	1.5	2.5	4	6	10	16
AWG	24	22	20	18	-	16	14	12	10	8	6
Pull out force N	10	15	20	30	35	40	50	60	80	90	100

Weidmuller also produces ferrules with collars that have been approved and listed by UL as conforming to the requirements of UL508 and DIN EN 60352-2 when crimped properly with Weidmuller crimp tools. There is no UL listing currently for ferrules, so UL uses the UL 486A standard for wire connectors and soldering lugs for use with copper conductors. All Weidmuller ferrules are UL listed from AWG 24 up to AWG 1 (with exception of AWG 2). The connectors are tested with a direct pull for one minute and withstand the following pull-out forces:

UL Pull-Out Force Testing

Cross section sq. mm	0.2	0.34	0.5	0.75	1.0	1.5	2.5	4	6	10	16
AWG	24	22	20	18	-	16	14	12	10	8	6
Pull out force N	22	35	58	89	35	133	222	311	356	400	445
Pull out force pound	5	8	13	20	-	30	50	70	80	90	100

These tests using Weidmuller crimping tools are certified by an UL-approved source regularly (usually on an annual basis).

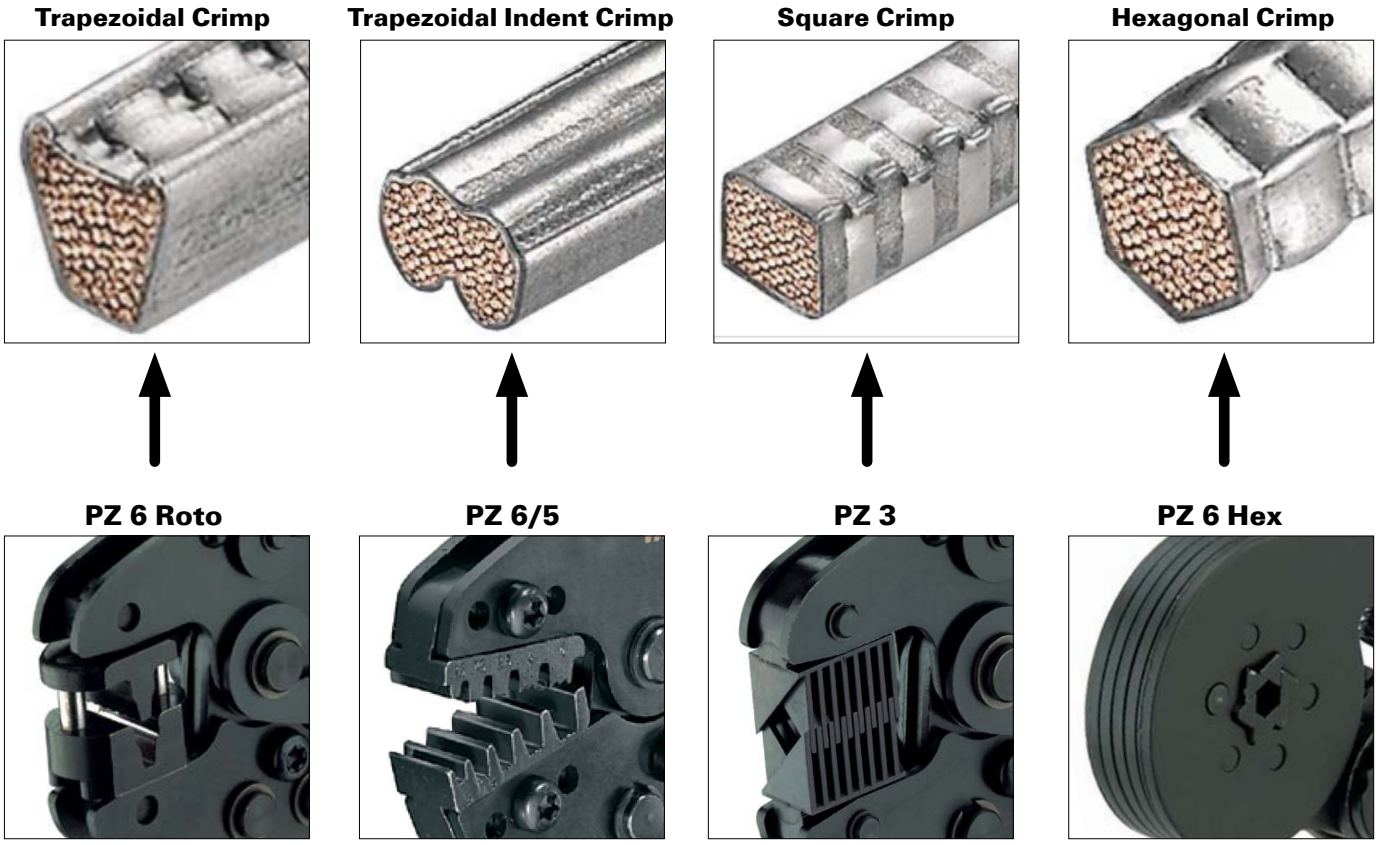
Weidmuller takes its testing one step further. In addition to testing ferrules and crimping tools to meet DIN and UL standards, we test them with the connection technologies—including screw clamp, tension clamp, and push-in connection—that are part of our Connectivity, DC, and electronic products. Our goal is to ensure a strong, durable, safe connection for customers regardless of their needs.

The Ultimate Source for Crimping Shapes

The strength of Weidmuller crimped connection is a direct consequence of the design of our crimping tools. They feature an integral ratchet mechanism with a disengaging option to produce optimum processing quality.

Another way we serve our customers is to offer crimping tools in an unsurpassed range of shapes. In this way, customers can choose the right shape for a specific application.

Weidmuller Crimping Shapes and Crimping Tools



A Comprehensive Range of Ferrules

Because we believe that ferrules offer unmatched advantages for stranded wire connections, we produce ferrules in a variety of shapes and configurations:

- Wire end ferrules with plastic collar from AWG 26 to 300MCM
- Wire end ferrules with plastic collar on reels for automatic machines from AWG 22 to 14
- Strips of wire end ferrules with plastic collars for stripax plus 2.5 from AWG 20 to 14
- Wire end ferrules for earth- and short-circuit-proof cable with a bigger plastic collar
- Twin ferrules for the connection of two wires from AWG 20 to 6
- Wire end ferrules without plastic collars from AWG 24 to 350 MCM

In addition, Weidmuller provides a full range of ferrules adhering to the DIN standards in three color codes (Weidmuller, DIN 46228, and "other").

The Cost-Efficient Approach to High-Quality Connections

The use of ferrules is one of the most obvious signs of a panel that is carefully designed and built. Its neat appearance, however, is ultimately a reflection of value gained by containing stranded wire at the point of connection. As such, the use of ferrules indicates a prudent allocation of resources. The incidental expense of ferrules and the time it takes to crimp them to the end of a wire pale in comparison to the delays and substantial costs of shorts and failed connections that occur when stranded wire frays or breaks. Simply put, by enabling high-quality, long-term connections, ferrules are the cost-efficient choice.