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Reduce the Risk of Equipment Failure with Efficient Wire Termination Solutions

This briefing is an executive summary of a webcast sponsored by Heilind Electronics and Panduit.

Introduction

When designing an electrical system, reducing the risk of failure is a top priority. By making the best selections and ensuring proper installation of the termination, your end product can meet industry standards for your current application. This paper highlights an efficient process to properly identify and install connections to ensure quality performance and reliability while reducing service work.

Reducing the Risk of Failure

There are several steps to take to reduce risk of failure when installing wiring. First, design with products that meet industry standards such as UL, CSA, or DFARS. Make sure the products you choose work in the application environment of the end product — not just where it's installed in the manufacturing facility. This will ensure reliability and performance over the life of the product.

Once you select the right products, proper crimping and installation are just as important as selecting the right product. You must have the right tools for a consistent result — not just one or two times, but over the installation. Products should be tested and certified with the connector and tool combination. Most users do not realize that the end product that must meet certification is not just the terminal on the wire — it's the terminal, the tool itself, and the wire that will achieve certification.

An efficient process for saving money is not solely about material and labor costs. An efficient process is what saves money and makes projects more profitable in the long run. Inspection should be the final step in an installation, which is an easy insurance policy for little investment.Take the time for quality — a bad crimp, if detected within the first few minutes, costs pennies. If it's within hours, it could be thousands of dollars. Within a day, it could be hundreds of thousands of dollars and this keeps escalating the longer it takes to identify a bad

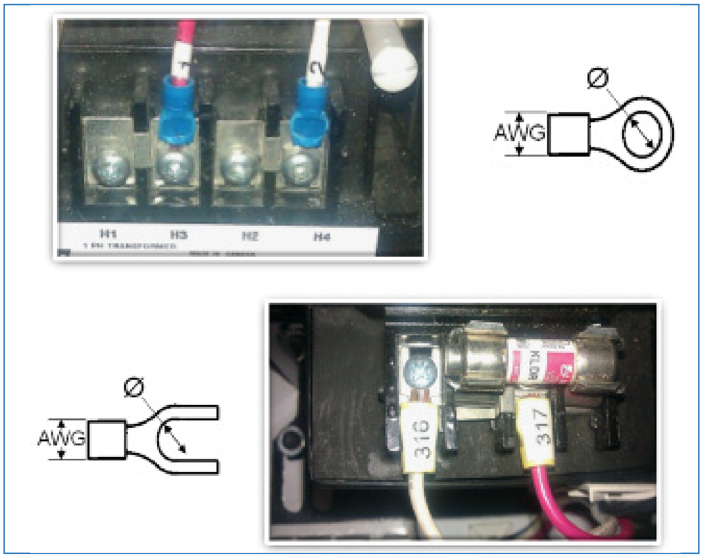


Figure 1. Ring and fork screw-down applications.

connection. It's all about reducing rework and making sure that customers receive the best-quality product.

Terminals and Ferrules

Terminals and ferrules go on the end of the wire — whether it's a terminal block, a screw-down connection point, or a fast on connector. The origin of the terminal is the ring terminal. It requires the operator to remove a screw, insert it through the ring terminal, and then re-attach it to the end device. Rings are very secure when crimping is done properly; the challenge is that they take time to install. So forks were developed since they were faster — the process consists only of loosening the screw and slipping the fork underneath, then tightening it down. Innovation continued and now there are switches and devices that have the male tab on them and disconnects that simply slip on the end device or the male tab and make it a very quick installation.

Best Practices

A best practice that may be overlooked is a simple one — it is knowing the voltage and current rating of the setup and choosing the appropriate wire size and insulation. If the wire

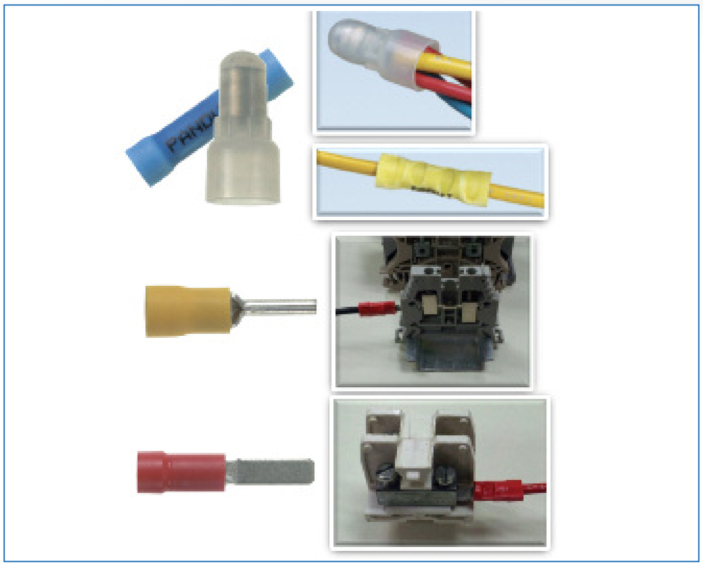


Figure 2. (Top to bottom): Splices and wire joints, pins, and blades are just a few connector options.

is not large enough in diameter to support the power expected of the wire, it may actually cause breaks in the wire, fusing, and failure.

Next, determine the appropriate terminal and/or ferrule, depending on what you're connecting to. With control panels getting smaller, manufacturers are transitioning from traditional terminal blocks with wide spacing and plastic dividers, to more modern terminal blocks with spring-loaded or mechanical fastening connection points. Connection types will vary for each style of terminal block. Rings and forks are more common for these older designs, while ferrules, blades, and pins are more common for newer models. With these newer solutions, you can save up to 30% more panel space for the same amount of connections.

With these potential space and cost savings in mind, there still are environmental conditions to take into consideration that are important for the decision on the appropriate terminal type and material. Non-insulated connectors are either cast or stamped plates of copper or brass that are formed into a ring, a fork, a disconnect, or ferrule. They are then tin-plated to prevent corrosion.

Even though there may be barriers and space between connections, insulating materials are increasingly more important for preventing failures like an electrical short. Different insulating plastics or specialty materials have different considerations based on the environment. The most important of which are nearby chemicals and operating temperature. These can deform the insulation and erode the connection to the point of failure. The insulating materials may also have flammability ratings or act differently based on humidity and moisture. These too will alter connections and risk performance and failure over time.

Industry standards also are very important. Some require a listing versus recognition. Recognition means that the product has been tested to a certain standard or testing criteria. A component may be used within a control panel and is a recognized component, but you still may have to test the assembled device. Listed components can stand on their own. This means the terminal or the ferrule has been tested, or the ferrule has been run through voltage testing, dielectrics, and heat aging. The pull force will also be tested to ensure the crimp was done properly and will hold under a certain load.

Applications

A high-vibration application could be a manufacturing facility with multiple moving components, conveyors, and stampings; transportation such as rails, aerospace, and heavy truck and bus; and white goods where there's a constant amount of motion and vibration. The challenge is intermittent connections that can come loose, causing increased temperature or faults. When there is increased temperature from a high-resistance connection, the acceleration of corrosion increases. Corrosion itself can also cause higher resistance or a failure of the connection altogether. To reduce the risk of failure from vibration, or the symptoms of it, special connectors or insulation crimping are an easy solution to improve the life of a connection.

There are special disconnects that have a tighter curl height, requiring more force to put them on; the chance of them coming off under high vibration is greatly reduced. The alternate solution is a ring and stud. Again, it involves taking the screw out of the connection to the device, putting that screw through the ring, and then torqueing that screw down at a proper tension to ensure it doesn't come off. It's a slower installation but provides a greater guarantee than other forms of termination.

Double crimping is also highly encouraged. Many new components have a metal insulation grip sleeve. If you've ever done a termination, you strip the wire and crimp the ferrule on the wire — a single crimp. The double crimp has an extra metal sleeve that actually crimps onto the insulation of the wire.

As mentioned previously, high temperatures can be an issue for corrosion and connection resistance. There are some applications where high temperatures are unavoidable as they exist in the geographic environment or from adjacent machinery. For these applications, the insulating and plating materials are very important. Some plastics or rubbers may smoke or melt, which may harm both workers and connections. Insulating materials that are halogen-free, have relevant flammability ratings, or high operating temperatures should be considered to avoid these dangers. Sometimes an insulating material may not be appropriate, in which case a bare connector can, and should, be used. With this in mind, bare connectors should be plated with materials of higher corrosion resistance and melting points. The most common Nickel-platings should suffice, although each option will have its pros, cons, and cost.

High-maintenance applications exist where connections need to be replaced quickly and easily. The challenge when removing connection points is putting them back on and ensuring reliability of the connection. Solutions may inlude ferrules crimped on the end of high-flex cabling. Flex cable on its own is not allowed for use within a control panel without being terminated by a ferrule. When put in the end device, high-stranded cables are screwed down into a mechanical terminal or captured by a trapping mechanism. High-flex cables can be anywhere from 32 to over a hundred strands, depending on the size of the bundle or the gauge of the wire. And when torque is applied to screw those bare wires down, they break, fracture, or flare out. A ferrule must be put on the end to create a solid cable for a more secure and reliable contact surface. For some applications, it may be impossible to fit an entire conductor

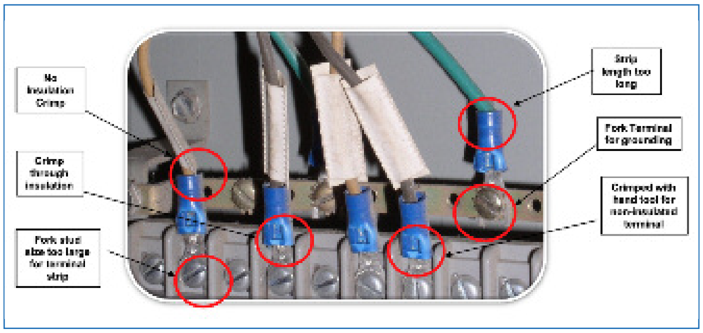


Figure 3. Common causes for misconnections.

into the terminal block or terminating apparatus due to its large diameter and lack of firm structure. For these instances, the ferrule not only helps the contact surface but also acts like an aglet might to a shoelace.

Disconnects and forks are also commonly used within high-maintenance applications. Disconnects are used in the white goods industry where there are a lot of switches with the male tab already installed on them. If you have to replace a system in this instance, it is easier to disconnect and reconnect this type of terminal than have to re-terminate a new one.

In printed circuit board applications, disconnects frequently occur. The biggest challenges are spacing of connector points, the voltage draw, and sizing disconnects. High temperatures occur by not properly spacing them or having the right size or number of termination points. You may split the voltage into multiple connection points to reduce the amount of heat. There needs to be quarter-inch spacing between a positive and a negative wire for incoming voltage or the disconnect will turn hard and brown.

In Figure 1, the top photo shows how the wires are spaced, and there is a plastic barrier between the termination points. That is actually a UL design that specifies the amount of distance that must exist between one connection point and the next to prevent a short. You can see in the bottom photo similar barriers and spacing exists in this application involving a fuse. This user experienced a fault and the initial thought was that there was an issue with the manufacturer's connectors or with the crimps that terminate them. Even though the terminals might be far enough apart, the fuse extends past these barriers and was the actual culprit for the short. It is important to be able to use concepts learned from one aspect of a standard to apply them as a best practice for something similar in principle. In this instance, the user could have assumed that the fuse should be spaced similarly to the connectors.

Proper Crimping

What happens if a connection is not consistent or if it's done incorrectly? An obvious result is intermittent or bad connections, but electrical shorts can also result due to bent back strands that may cause delay or malfunctions to the end product the connection supports. This can be catastrophic to the product, or even be deadly to a user.

To avoid these hazards, first select the proper crimping tool. Everything typically is applied by a die-type controlled cycle mechanism, whether that's in a manual tool, a battery-powered tool, or a hydraulic press tool.

The lowest-volume, most economical, and most common tool is the plier-type tool. It comes in a variety of shapes and sizes and packs the most functions into the tool such as wire cutters, wire strippers, bolt cutters, crimping pockets, and strip length gages. These tools are convenient, but not always the most reliable.

Controlled-cycle tools have a more precise mechanism to create a consistent crimp that is almost entirely independent from the operator's technique or abilities. As long as the terminal or ferrule is properly oriented, the tool will consistently control the output force of the crimp. These tools are usually more expensive for this reason, and will only serve this single purpose.

The next step up are micro-crimping tools, which are battery-powered controlled-cycle tools. These tools have an ergonomic design and a wide range of crimping capability to reduce repetitive motion injuries. They are more expensive than manual controlled-cycle tools, but it depends on the application and the return on investment from increased efficiency.

Automated reel-fed applicators pack large hydraulic power into an applicator that houses a different type of crimp die and cutting mechanism. They efficiently and consistently make the same crimp onto a wire and eject the crimped solution while continually feeding more connections.

An additional consideration when making your tooling decisions is the relevance to a connections agency listing/standing. Not all tools and dies will be compatible with all connectors available to the market. Certain manufacturers may require their products to be crimped with a specific set of conditions to ensure proper performance.

Once all of the appropriate design and tooling conditions are accounted for, the final step is making the crimp. This comparatively simple step still has its own technicality and nuance. The orientation of a crimp based on the terminal barrel is the most important consideration. The crimp should be made perpendicular to the terminal's tongue (or circumferentially for ferrules) and should be placed close to the middle of the barrel ensuring that it captures all wire strands. This crimp will either be done with a beveled, oval-shaped die for barrels with soldered/brazed seems, or by indention from a protruding finger of the die for barrels that are simply butted together. After this initial crimp is accomplished, the secondary insulation crimp should be done the same way. It may be important to know that some tools and dies may do each step at once for simplicity.

The Importance of Inspection

After selecting the appropriate terminal, selecting the correct tool, and making a proper crimp, the termination should be inspected. This is perhaps the most critical step in the crimping process. Figure 3 shows common causes for misconnections. The upper left circle is highlighting a lack of an insulation crimp. These vinyl-insulated terminals have enough rigidity to the barrel insulation to add a strain relief if a second crimp is added.

The lower left circle may be difficult to discern based on resolution, but this stud size of this fork terminal is too large for the fastener/screw that is being used.

The two central circles are identifying the most concerning errors in the crimping process. The crimps appear to be too forceful with the insulation being broken through to the metal contact of the terminal. This would cause high resistance and increased likelihood of a fault. The crimp type is also wrong for these insulated terminals, as it seems to have been crimped by a indent-type die for uninsulated terminals instead of the beveled-type die.

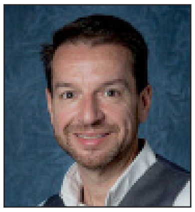
The lower right circle is identifying an issue with misapplication. It is ill-advised to use a fork-style terminal for a grounding or bonding connection. Because these connections are inherently important for safety, they should be as secure as possible and done with a ring-style terminal.

The last circle, in the upper right, is highlighting a very common error regarding strip length. This connection is susceptible to fraying and severing to cause a short.

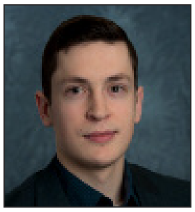
Conclusion

The crimp, within the scope of any project, is a small piece of work but even one improper connection can be the downfall of an overall wire termination assembly. The cost to repair one of these connections is low at first, but can escalate to total failure of a system or personal injury. Even though it's a small thing, success depends on the crimp.

Authors



Vince Barone leads several teams that focus on developing automated tooling solutions and wiring components. He holds various patents and has authored articles on increasing productivity with quick termination tools and other solutions. Currently, he is responsible for the continued development and growth of the Panduit Stronghold product offering and continues to drive key partner relationships within the industry.



Brendan Haas is the Product Manager of terminals, Reel Smart, and wiring duct products at Panduit with an OEM focus. He brings an industrial construction background to the role by previously managing the company's grounding and bonding solutions. He has contributed to Panduit's technical literature by writing white papers and reviewing articles on subjects like industry standards or project profitability improvements.

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