

Wire Wrapping: The Solderless Connection

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Origins Of The Technology

Wire Wrapping is a technology that has been with us for over fifty years, and is still going strong in various telecommunications and electronics applications. It was originally developed in the late 1940's by Bell Labs in the U.S.; they needed to develop a new system of interconnection of the copper cabling in their local exchange facilities, also known as Central Offices. Up until that time, soldering was the commonly used method for cable interconnection – but this approach created several problems in these applications.

First and foremost, soldering represented a reliability problem. Solder joints require a certain set of skills to effectively complete, and yet the joints themselves can easily fail if the soldering process isn't just right – and it is difficult to measure the acceptability of a solder joint and quite messy to attempt rework of a defective one. Mechanically it is brittle, weakens with age and varies widely in strength from connection to connection. Also, soldering is prone to 'solder splash,' or the exfoliation of small balls of molten solder from the area of the solder joint. This can cause shorts and burn damage in adjacent electrical and electronic gear. And if the soldering iron is not properly grounded, there is a risk of electrical discharge to the costly network elements in the facility.

Soldering is also problematic in a couple of other respects. A power supply is necessary to operate a soldering iron, and given the need for a technician to move continuously up and around the MDF (main distributing frame) in a Central Office combined with the relative scarcity of electrical power outlets in these facilities, the use of lengthy extension cords is required. This not only reduces productivity due to handling and repositioning the cords, but also constitutes a safety hazard as cords can become entangled in ladder steps and terminal blocks on the MDF. Furthermore, an operator cannot visibly determine whether a soldering iron is hot, so there is a danger of injury due to burns and of accidentally burning equipment with the hot iron. And there are time-consuming steps that are required in terms of preparing the wire ends for soldering, such as the application of solder flux, which leaves a nasty residue.

So the engineers at Bell Labs set out to create a purely mechanical interconnect technology that would provide acceptable reliability in a safe, effective manner. And that is precisely what they achieved.

How Does It Work?

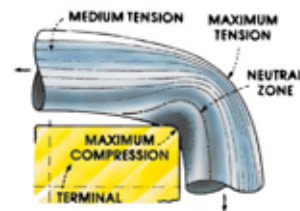
Wire wrapping is a process for connecting stripped (un-insulated) copper wire to a terminal to complete an electrical circuit. The wires are tightly coiled around the terminal through the motion of a rotating element, called a bit. The bit is fabricated from solid steel rods and has a large central hole machined along its axis for slipping the tool over the terminal; the terminal will remain inside this cavity as the bit rotates. The top surface of the bit has a wire slot, a groove that is machined axially along the outer diameter, which accepts the length of stripped wire that is to be wrapped. The front or face of the bit, where the wire first makes contact prior to being coiled around the terminal, is shaped to apply the proper tension to the wire during the wrap. This contour also guides the wire into a helix that is tightly spaced and uniform. Each bit is designed to handle a specific combination of wire gauge, wire insulation diameter and terminal post geometry. While in operation, the bit is surrounded by a stationary metal tube called a sleeve. The sleeve retains the bit in the collet of a wire-wrapping tool, which drives the bit as it spins. It also keeps the wire in the slot during the wrapping process and protects the worker from the rotating bit.

As the bit rotates, it pulls the wire across the sharp corners of the terminal, which is either square or rectangular in cross-section. This process subjects the wire to tremendous levels of tension and compression, typically 100,000 PSI at the terminal's edge (see Figure 1). The wrapping action causes the oxide layer on both wire and terminal to be crushed or sheared away, and the helical stress applied to the terminal by the wrapped wire actually causes the metals of the terminal and the wire to diffuse. This results in a connection of superior mechanical strength with very low electrical resistance. It also yields a gas-tight connection with a design life of 40 years, yet one that can easily be unwrapped to correct any wiring errors or to replace the equipment to which the wire is terminated. This high level of reliability and environmental resistance also makes wire wrapping a preferred method for military and field equipment.

FIGURE 1

METAL - TO - METAL CONTACT

By bending the wire around the sharp corner of the terminal, the oxide layer on both wire and terminal is crushed or sheared, and a clean, oxide-free metal-to-metal contact is obtained.



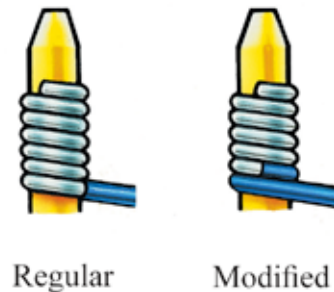
The number of turns in any given wire wrap connection is determined by the particular wire size. These parameters relate directly to electrical conductivity and mechanical strength of the resulting connection. However, if a manufacturing specification requires a wrap with more turns, wire with correspondingly longer lead lengths or hand stripping may be required.

There are two types of wire-wrapped connections: regular and modified (see Figure 2). In a “regular” connection, only un-insulated wire is wrapped around the terminal. A “modified” wrap, which requires a modified bit, coils about 1 1/2 turns of insulated wire around the terminal in addition to the bare wire. This method greatly improves a connection's mechanical stability, such as resistance to vibration, in cases where the wire diameter is small and its mechanical strength is low. The most important element to consider when choosing either wrap method, then, is the size wire being used. A standard wrap is generally used for 26 AWG and larger diameter wires; a modified wrap, on the other hand, is used almost exclusively for 28 and 30 AWG wires. In either case, the wrap style affects only the connection's mechanical stability; they both provide identical electrical characteristics, yielding a resistance of normally less than 3 ohms.

FIGURE 2

TYPES OF WRAP

A “Regular” bit wraps the bare wire around the terminal. A “Modified” bit wraps a portion of insulation around the terminal in addition to the bare wire. This greatly increases the ability to withstand vibration.



The four most common wire wrapping mistakes are (a) pressing too hard, which can lead to over-wrapping; (b) not pushing the stripped end of the wire all the way into the bit, which causes insufficient turns; (c) removing the tool before completing the wrap, which can result in spiral and open wraps; and (d) choosing the wrong bit and sleeve, which can cause problems ranging from pigtailed to loose wraps.

Tool Selection Is Critical

Although the basic technology of wire wrapping doesn't vary from one application to another, the specific tool that is selected will greatly affect cost, efficiency and ergonomics. The simplest and lowest in cost are the hand wrapping and unwrapping tools, which have the basic construction style of a screwdriver and are twisted by hand to perform wrap or unwrap operations. With the hand tools, the bit and sleeve are integral to the handle and each tool is dedicated to a specific wire gauge size or range of sizes. These tools are especially useful for repair work and prototyping, but are not efficient when performing more than 50-100 wrap operations per day.

One step above the simple hand tool is the manual ‘squeeze’ tool, which is powered by squeezing a trigger with four fingers of the hand. The manual tools feature a bit holder or ‘collet’ which allows them to accept bits and sleeves that are designed for the various application parameters. Manual tools are often used in applications of roughly 50-200 wraps per day, but are not recommended beyond that volume as this can lead to operator fatigue and repetitive stress. Insulated aluminum manual tools are suggested for applications where the wiring is electrically live.

Battery- and electric-powered tools are widely used in higher volume applications, which can include factory production or telecom equipment connection. These tools employ the same bits and sleeves that are used in conjunction with the manual tools. They are generally more expensive than hand or manual tools but provide a much greater level of efficiency and operator protection from the risk of repetitive stress injuries, particularly when wrapping or unwrapping several hundred times or more in a given day. When selecting power tools, the user first needs to determine his/her preference for electric vs. battery power. Another option, known as ‘back-force,’ is available for those who are concerned about over-wrapping; this feature helps to absorb some of the extra pressure that an untrained user might apply. Also, there is a common myth that tool speed is important with respect to tool function; actually, a wrap performed very slowly with a hand tool is equivalent in quality to one made with a power tool operating above 4,000 RPM. Regardless of speed, the geometry and action of the bit face will pull the wire around the corners of the terminal with the appropriate tension, thus imparting a consistent level of mechanical and electrical integrity of the connection.

Despite its longevity in the telecommunications and electronics industries, wire wrapping is a proven technology that offers superior reliability along with ease of use across a wide range of tool types and applications. Though some may view it as a mature technology, it is quite likely that it will be with us for many years to come.