by Richard C. Hoffman and
Robert S. Mroczkowski
Courtesy of AMP Incorporated
Harrisburg, PA

The development of crimping technology began in the 1940's with the intention of providing an alternative to soldering. The major drawback of soldering at that time was the operator sensitivity of the predominantly hand or dip soldering process. Reliable soldering depends on the proper control of cleaning/fluxing during preparation of the wire/terminals and time/temperature during the soldering process itself. "Cold joints," resulting from improper time/temperature relationships, could be difficult to identify and, therefore, had the potential for field failures.

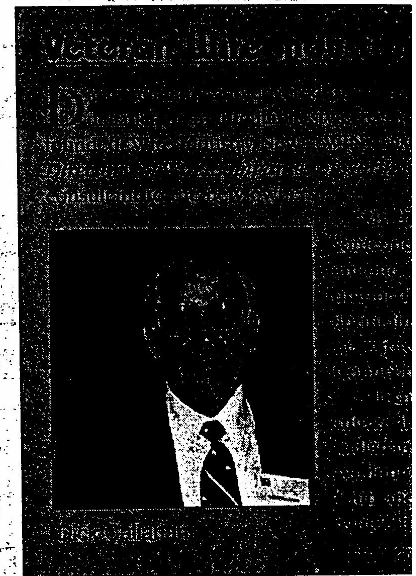
The crimping process provides an opportunity to reduce or eliminate operator sensitivity through the development of crimping technologies which are capable of producing repeatable and reliable crimped connections. Today a wide variety of crimping systems are used over a broad range of electrical and electronic applications.

A crimping system consists of:

- a specific wire size ( or range of sizes)
- a crimp terminal suitable for the wire(s),
- a crimping tool specific to the selected wire/terminal combination.

The reason such a system is critical to performance is that *controlled* deformation of the wire/terminal combination by the crimping tool produces the metallurgical/mechanical interfaces which determine the *mechanical and electrical* performance of the crimped connection. Control of the deformation process comes from the wire/terminal selection process, which determines the initial cross sectional area, conductor(s) and terminal, which will be crimped, and the geometry of the tooling, which determines the final cross sectional area of the crimped connection.

Given this brief overview some additional discussion of the crimping process and crimped connection geometries, the relationship between deformation and crimped connection performance, and inspection procedures to ensure reliable crimping processes are in order.



## CRIMP TYPES AND THE CRIMPING PROCESS

There are two major styles of crimp terminals: open barrel and closed barrel. "Barrel," more correctly "crimp or wire barrel," refers to the section of the terminal into which the wire is inserted

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## Good Crimps Don't Just Happen

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and the crimp barrel is then deformed around the conductors during the crimping process, as will be discussed. Examples of each are provided in illustration one.

the insulation support barrel is exactly as the name implies. The insulation support barrel is deformed around the wire to support, or grip, the insulation and provide the equivalent of a strain

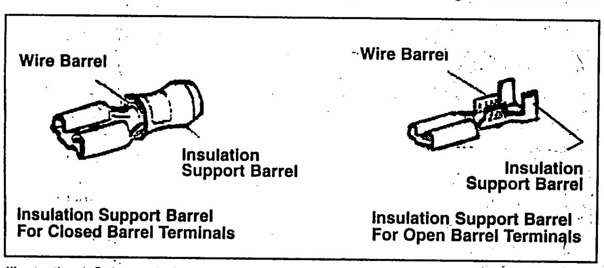



Illustration1:Schematic illustration of open and closed barrel crimp terminals.

The differences are clear, closed barrel terminals require that the wire be inserted axially and vertical placement is possible in open barrel terminals.This difference translates into significant increases in process speed when open barrel terminals are used because the target area for wire insertion is larger and the vertical placement easier to implement. Open barrel terminals are the preferred type for high volume automatic equipment also, but in general, the volumes will be lower. Closed barrel terminals are often used loose piece with hand tools and semiautomatic equipment.

Two additional features of crimp terminals merit attention: the insulation support or grip, and preinsulation of closed barrel terminals.The function of

relief. Insulation support features in open and closed barrel terminals are also illustrated in illustration two. Insulation supports provide a significant improvement in the stability of crimped connections in high vibration environments as well as enhancing tensile pull strengths.

Pre-insulated crimps are available only in closed barrel terminals and can provide desirable assembly advantages. In essence a plastic insulator is attached to the terminal by a variety of means and the crimping process is performed through the insulation. This, of course, requires that the insulating material have sufficient ductility to withstand the deformation of the crimping process.

Illustration two contains a schematic of a crimping process, in this case for an open barrel terminal.The major stages in crimping include:

- gathering the strands of the prestripped wire.
- deformation of the barrel/conductors
- a controlled stop to limit the deformation.

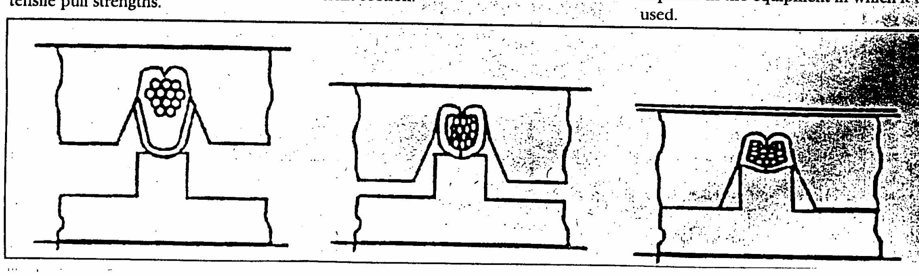
The controlled stop establishes the crimp height which is a monitor of crimp quality as well as process control. Control of the deformation of the barrel and conductors during crimping is critical to crimped connection performance as will be discussed in the next section.

### CONTROLLED DEFORMATION AND CRIMPED CONNECTION PERFORMANCE

All mechanical methods of making electrical connections must meet the same general requirements which include:

- establishing a metallic contact interface.
- maintaining adequate mechanical strength.
- ensuring the stability of the contact interface over time.

Establishing a metallic contact interface is necessary to ensure both a low electrical resistance and high mechanical strength connection. Some minimum level of mechanical strength is required to survive the handling operations which will be experienced during assembly of the product in which the wires or connectors are used. Clearly, the contact interface, since it provides both the electrical and mechanical characteristics of the connection, must have sufficient stability to survive the various disturbances. mechanical, electrical and thermal, to which the connector will be exposed in the equipment in which it is used.



There are two basic mechanisms for *establishing* and *maintaining* permanent contact interfaces. They are *cold welding* and the generation of an appropriate *residual force* distribution. These mechanisms are interdependent and both contribute to the reliability of permanent connections.

### *Cold Welding*

Cold welding always occurs when two metallic surfaces are brought together under an applied force and sliding or wiping actions, which is the case in the crimping process.

### *Residual Forces*

An "appropriate residual force distribution" is one which acts to maintain a positive force on the contact interface. While the residual force distribution in a crimp is quite complicated a simple example indicates their general behavior. Residual forces are developed during crimping due to the differences in elastic recovery between the conductor and the crimp barrel as the crimp tooling is removed. If the conductors tend to spring back more than the crimp barrel, the barrel will exert a compressive force on the conductors which will maintain the integrity of the contact interface.

### *Crimping Mechanics*

The essentials of the mechanics of the crimping process can be understood by discussion of the data shown in illustration three. The mechanical strength, as measured by the tensile strength, and the electrical performance, as measured by millivolt drop or crimp resistance, of the crimped connection are plotted versus the deformation of the wire/terminal. It should be noted that electrical performance *increases* as millivolt drop and resistance *decrease*. The data in illustration three are schematic only and not intended to represent any specific crimping system. The relative shapes and magnitudes of such curves are, of course, dependent on materials and terminal and tooling geometries. The following description of crimping kinetics is also general, but representative of typical crimping processes.

Consider first, the mechanical strength curve. Pull strength increases slowly as deformation begins. At this point the mechanical strength arises

mechanical strength with deformation reflects this fact. The peak in the pull strength occurs in the region where the combined cross sectional area of the terminal and the conductors is reduced below that of the undeformed areas. The tensile strength of a crimped connection can approach that of the wire itself.

The electrical performance data has a different shape than the mechanical strength, showing a broad plateau in performance followed by an decreasing tail. As mentioned, the cold welding process results in the metallic interfaces which are responsible for the electrical properties of the interface. The same description of the deformation kinetics, therefore, applies. The different shape of the curve arises from the fact that the electrical performance has a "minimum" value which is realized when the contact area approaches that of the cross section of the wire. Additional contact area results only in marginal decreases in resistance. The additional area, however, may be important when the stability of the crimped joint is taken into account. Resistance increases again when the cross sectional area is reduced below that of the original conductor/terminal cross section.

The optimum values of mechanical strength and electrical performance do not, in general, occur at the same deformation. The design deformation is derived from a tradeoff of the mechanical and electrical requirements of the application in which the crimp is to be used. Once an "optimum" deformation is selected, it is controlled by the tooling, in particular by controlling the crimp height, as will be discussed.

### *Summary*

The electrical and mechanical performance of a crimped connection results from a controlled deformation of the conductors and crimp barrel which produces micro cold welded junctions between the conductors and between conductors and the crimp barrel. These junctions are maintained by an appropriate residual stress distribution within the crimped connection which leads to residual forces which maintain the stability of the junctions.

## INSPECTING CRIMPED CONNECTIONS