

QUALITY CRIMPING
HANDBOOK
Order No. 63800-0029

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SECTION 1

INTRODUCTION TO CRIMP TECHNOLOGY

Developed to replace the need to solder terminations, crimping technology provides a high quality connection between a terminal and a wire at a relatively low applied cost. The methods for applying crimp terminations depend on the application and volume, and range from hand-held devices to fully automated systems.

The application methods include a basic hand tool, a press and die set, a stripper crimper, or a fully automatic wire processing system. However, no matter what method is used, the setup of each tool is critical for achieving a quality crimp.

Today, many OEM companies are using Statistical Process Control (SPC) to continuously improve their crimp terminations. Crimp termination is a complex process and to ensure consistent quality it is necessary to understand the variability and inter-relational interactions that the technology involves.

Without a thorough understanding of the crimping process, and all the factors that can affect it, the result may not meet expectations. The three key elements in the crimping process are the terminal, the wire, and the tooling.

Terminal

For most applications, it is not economically practical for connector manufacturers to design a terminal to accept one wire size, one wire stranding, and one insulation diameter (UL type). Most terminals accommodate many wire sizes, stranding, and a range of insulation diameters, and the terminals are designed to meet acceptable levels over this entire range.

Wire

The wire stranding and insulation type can vary widely within one wire size. For example, there is more than 18% more material in an 18 AWG by 19-strand wire than an 18 AWG by 16-strand wire. The insulation diameter of an 18 AWG wire can range from 1.78mm (.070") to over 4.57mm (.180"). Wire strands can be copper, tinned, over coated, or top coated. Wire insulation materials, thickness, and durometers vary from application to application.

Tooling

What type of tooling does the application require? Does the application require hand stripping of the wire or does the volume dictate an automatic wire-stripping machine? Does the application and volume require hand tools, press and die, or fully automatic wire process machines? Crimping with a manual hand tool, semi-automatic press and die, or fully automatic wire processor, all involve different levels of variability. The terminal, wire, and type of application tooling all affect the quality of the completed terminations.

SECTION 2

PURPOSE

This handbook provides general guidelines and procedures for understanding and achieving acceptable crimp terminations. A glossary in Section 4 lists common terms and definitions. Section 5 lists the tools that are necessary to take accurate measurements and evaluate the crimp's acceptability.

The tooling setup is critical in determining the quality of the finished crimp. The attributes that need to be considered include crimp height, conductor brush, bell mouth, cut-off tab, strip length and insulation position. Variability in one or more of these attributes can reduce the measured pull force. It can be difficult to establish acceptable variability limits because the attributes all interact with one another.

For example, a track adjustment for bell mouth also will change the cut-off tab length and the insulation wire position while strip length and wire locations affect the conductor brush and insulation position. Adjusting the insulation crimp height may result in a slight change to the conductor crimp height measurement. It may be necessary for the setup person to make multiple adjustments before establishing an optimal setup.

The order the setup is done may help reduce the number of repetitions required for an optimum setup. Section 6 has a flowchart for a process setup while Section 9 is a troubleshooting guide for common problems. Using Statistical Process Control (SPC) during the crimping process can help minimize the amount of defects. Section 8 provides a general explanation of the benefits of using SPC.

This handbook is structured so that parts, or all, of its contents can be used as a procedural guide for ISO requirements.

SECTION 3

SCOPE

This handbook is intended for Molex customers who are crimping Molex open barrel crimp terminals and are using Molex tooling, primarily in semiautomatic or automatic wire processing termination methods.

The handbook's contents may slightly differ from other connector manufacturers' guidelines or individual company procedures.

This handbook provides a basic overview of what to look for in an acceptable crimp. It is not intended to replace individual product and/or tooling specifications.

Individual terminals or applications may have special requirements. Tooling limitations also may not permit an attribute to be adjusted to meet optimum requirements.

SECTION 4

DEFINITIONS

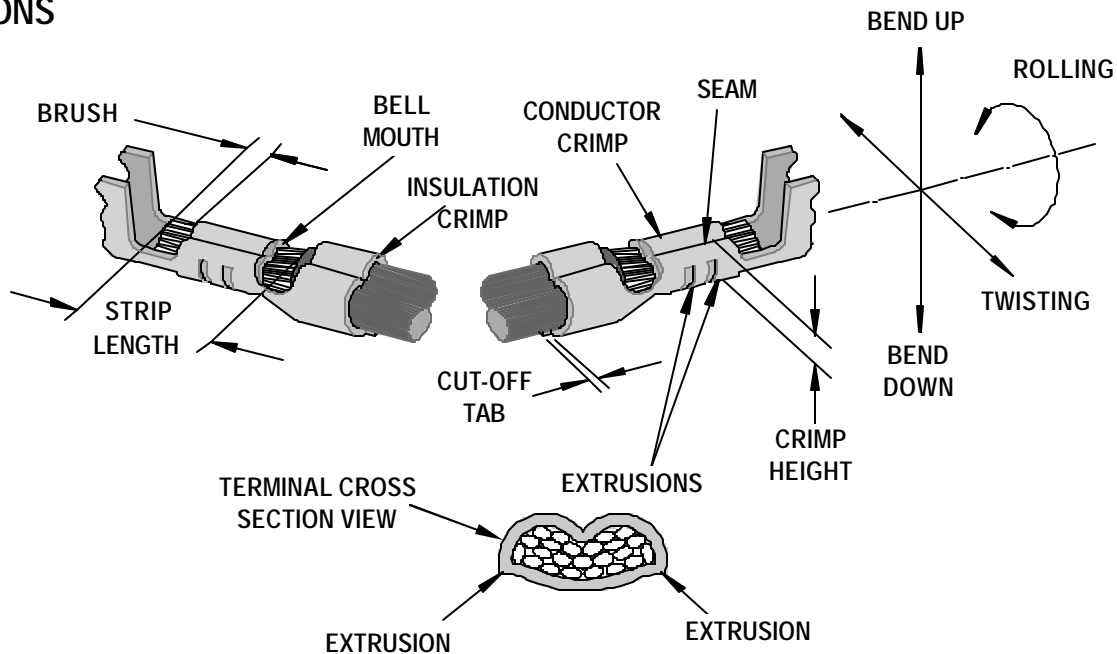


Figure 4-1

Anatomy of a Crimp Termination (Figure 4-1)

- **Bell Mouth (Flare)**
The flare that is formed on the edge of the conductor crimp acts as a funnel for the wire strands. This funnel reduces the possibility that a sharp edge on the conductor crimp will cut or nick the wire strands. As a general guideline, the conductor bell mouth needs to be approximately 1 to 2 times the thickness of the terminal material. (Consult individual terminal specification requirements).
- **Bend Test**
One way to test the insulation crimp is by bending the wire several times and then evaluating the movement of the insulation and wire strands. As a rule, the insulation crimp should withstand the wire being bent 60 to 90 degrees in any direction, several times. Use care when working with small wire sizes so the wire at the back of the insulation crimp does not shear.
- **Conductor Brush**
The conductor brush is made up of the wire strands that extend past the conductor crimp on the contact

side of the terminal. This helps ensure that mechanical compression occurs over the full length of the conductor crimp. The conductor brush should not extend into the contact area.

- **Conductor Crimp**
This is the metallurgical compression of a terminal around the wire's conductor. This connection creates a common electrical path with low resistance and high current carrying capabilities.
- **Conductor Crimp Height**
The conductor crimp height is measured from the top surface of the formed crimp to the bottom radial surface. Do not include the extrusion points in this measurement (See Figure 4-1). Measuring crimp height is a quick, non-destructive way to help ensure the correct metallurgical compression of a terminal around the wire's conductor and is an excellent attribute for process control. The crimp height specification is typically set as a balance between electrical and mechanical performance over the complete range of wire stranding and coatings, and terminal materials and plating. Although it is possible to optimize a crimp height to individual wire stranding and terminal plating, one crimp height specification is normally created.

■ **Cut-off Tab Length**

This material protrudes outside the insulation crimp after the terminal is separated from the carrier strip. As a rule, the cut-off tab is approximately 1.0 to 1.5 times terminal material thickness. (Consult individual terminal specification requirements). A cut-off tab that is too long may expose a terminal outside the housing or it may fail electrical spacing requirements. In most situations, a tool is set-up to provide a cut-off tab that is flush to one material thickness.

■ **Extrusions (Flash)**

These small flares form on the bottom of the conductor crimp resulting from the clearance between the punch and anvil tooling. If the anvil is worn or the terminal is over-crimped, excessive extrusion is the results. An uneven extrusion may also result if the punch and anvil alignment is not correct, if the feed adjustment is off, or if there is insufficient/excessive terminal drag.

■ **Insulation Crimp (Strain Relief)**

This is the part of the terminal that provides wire support for insertion into the housing. It also allows the terminal to withstand shock and vibration. The terminal needs to hold the wire as firmly as possible without cutting through to the conductor strands. The acceptability of an insulation crimp is subjective and depends on the application. A bend test is recommended to determine whether the strain relief is acceptable for each particular application.

■ **Insulation Crimp Height**

Molex does not specify insulation crimp heights because of the wide variety of insulation thickness, material, and hardness. Most terminals are designed to accommodate multiple wire ranges. Within the terminal's range, the strain relief may or may not completely surround the diameter of the wire. This condition will still provide an acceptable insulation crimp for most applications.

1. A large strain relief should firmly grip at least 88% of the wire.

2. A smaller strain relief should firmly grip at least 50% of the wire and firmly hold the top of the wire.

To evaluate the insulation crimp section, cut the wire flush with the back of the terminal. Once the optimum setting for the application is determined, it is important to document the insulation crimp height. Then, as part of the setup procedure, the operator can check the crimp height.

■ **Insulation Position**

This is the location of the insulation in relation to the transition area between the conductor and insulation crimps. Equal amounts of the conductor strands and insulation needs to be visible in the transition area. The insulation position ensures that the insulation is crimped along the full length of the insulation crimp, and that no insulation is crimped under the conductor crimp. The insulation position is set by the wire stop and strip length for bench applications. For automatic wire processing applications, the insulation position is set by the in/out press adjustment.

■ **Strip Length**

The strip length is determined by measuring the exposed conductor strands after the insulation is removed. The strip length determines the conductor brush length when the insulation position is centered.

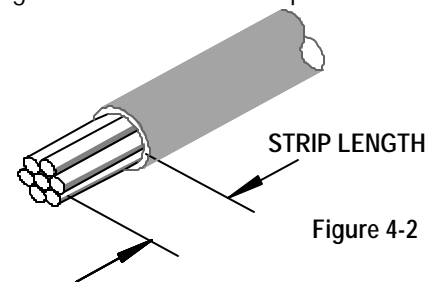


Figure 4-2

■ **Process**

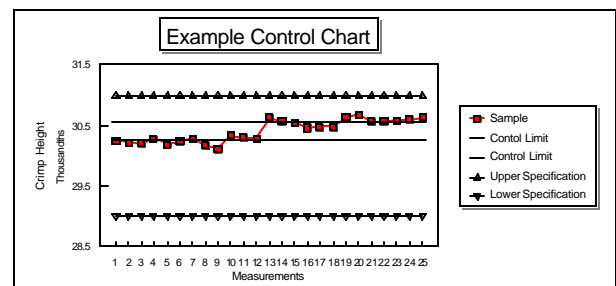


Figure 4-3

The combination of people, equipment, tooling, materials, methods, and procedures needed to produce a crimp termination. Process Control is used to track attributes over time to aid in the detection of change to the process. Detecting a process change when it happens helps prevent many thousands of bad crimps.

■ **Pull Force Testing**

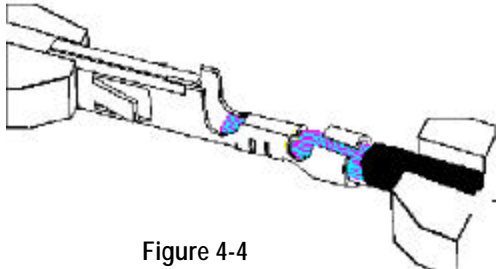


Figure 4-4

Pull force testing is a quick, destructive way to evaluate the mechanical properties of a crimp termination. Pull force testing results out of allowed range are good indicators of problems in the process. Cut or nicked strands in the stripping operation, lack of bell mouth or conductor brush, or incorrect crimp height or tooling will reduce pull force tests results. Wire properties and stranding, and terminal design (material thickness and serration design), also can increase or decrease the value of the results of a pull force levels.

If results of a pull force tests are within an allowed range, it assures that proper crimp force has been applied during crimping. It is crucial as, when making a crimp, enough force must be applied to break down the layer of non-conductive oxides that

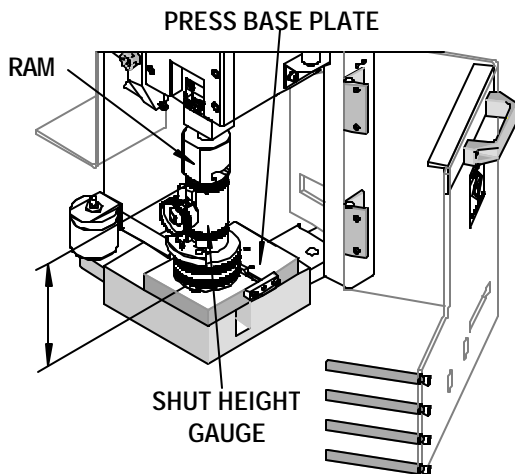


Figure 4-5

may build up on the stripped conductor and the tin-plating on the inside of the terminal grip. This is necessary to provide a good metal-to-metal contact. If this does not occur, resistance can increase. Over-crimping a crimp termination will reduce the circular area of the conductor and increase resistance.

■ **Shut Height**

This is the distance (at bottom dead center on a press) from the tooling mounting base plate to the tooling connection point on the ram of the press.

■ **Terminal Position**

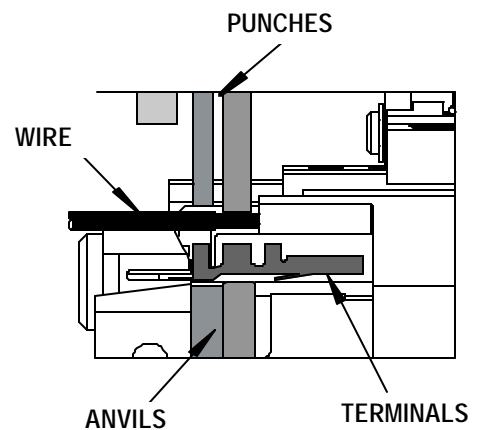


Figure 4-6

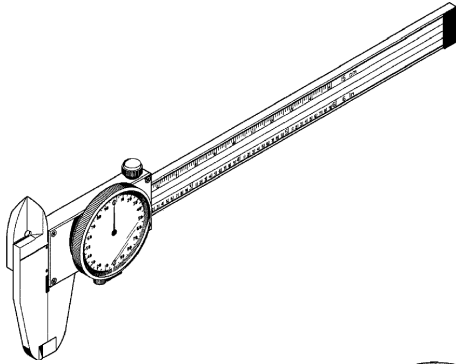
The terminal position is set by the alignment of the terminal to the forming punch and anvils, and the carrier strip cut-off tooling. The tool set-up determines conductor bell mouth, cut-off tab length, and terminal extrusions

SECTION 5

ASSOCIATED MATERIALS

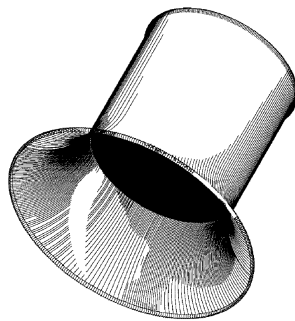
- **Caliper**

A gauge, consisting of two opposing blades. It is used for measuring linear dimensional attributes.



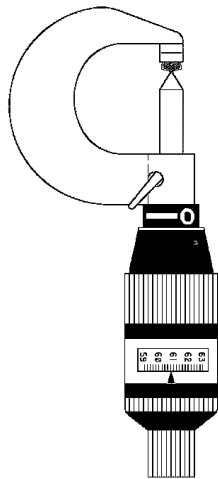
- **Eye Loupe**

This is an image magnification tool, normally 10 times power or greater, which is used in the aid visual evaluation of a crimp termination.



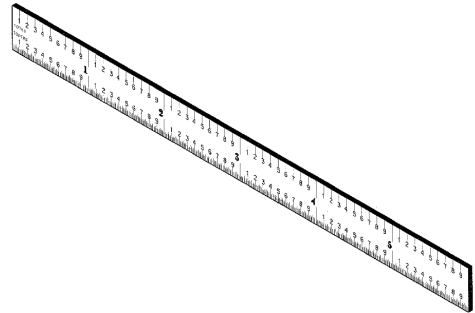
- **Crimp Micrometer**

This is a micrometer specifically designed to measure crimp height. The measurement is taken in the center of the crimp so the conductor bell mouth does not influence it. It has a thin blade that supports the top of the crimp while a pointed section determines the bottom radial (curved) surface.



- **Ruler (Pocket Scale)**

This is used to measure the length of bell mouth, cut-off tab, conductor brush, strip length, and estimate wire position. The recommended minimum resolution is 0.50mm (.020").

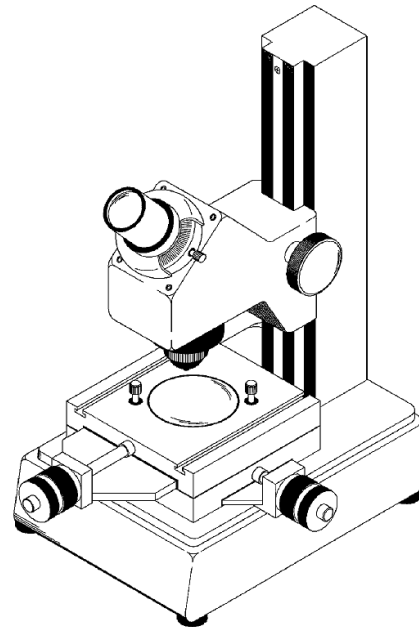


- **Pull Tester**

A device used to determine the mechanical strength of a crimp termination. Most pull testing is done with a device that clamps the wire, pulls at a set speed, and measures force by means of a load cell. A pull tester also can be as simple as hanging fixed weights on the wire for a minimum of one minute.

- **Toolmaker's Microscope**

This is used for close visual evaluation and statistical measurement of bell mouth, cut-off tab, conductor brush, wire position and strip length.



SECTION 6

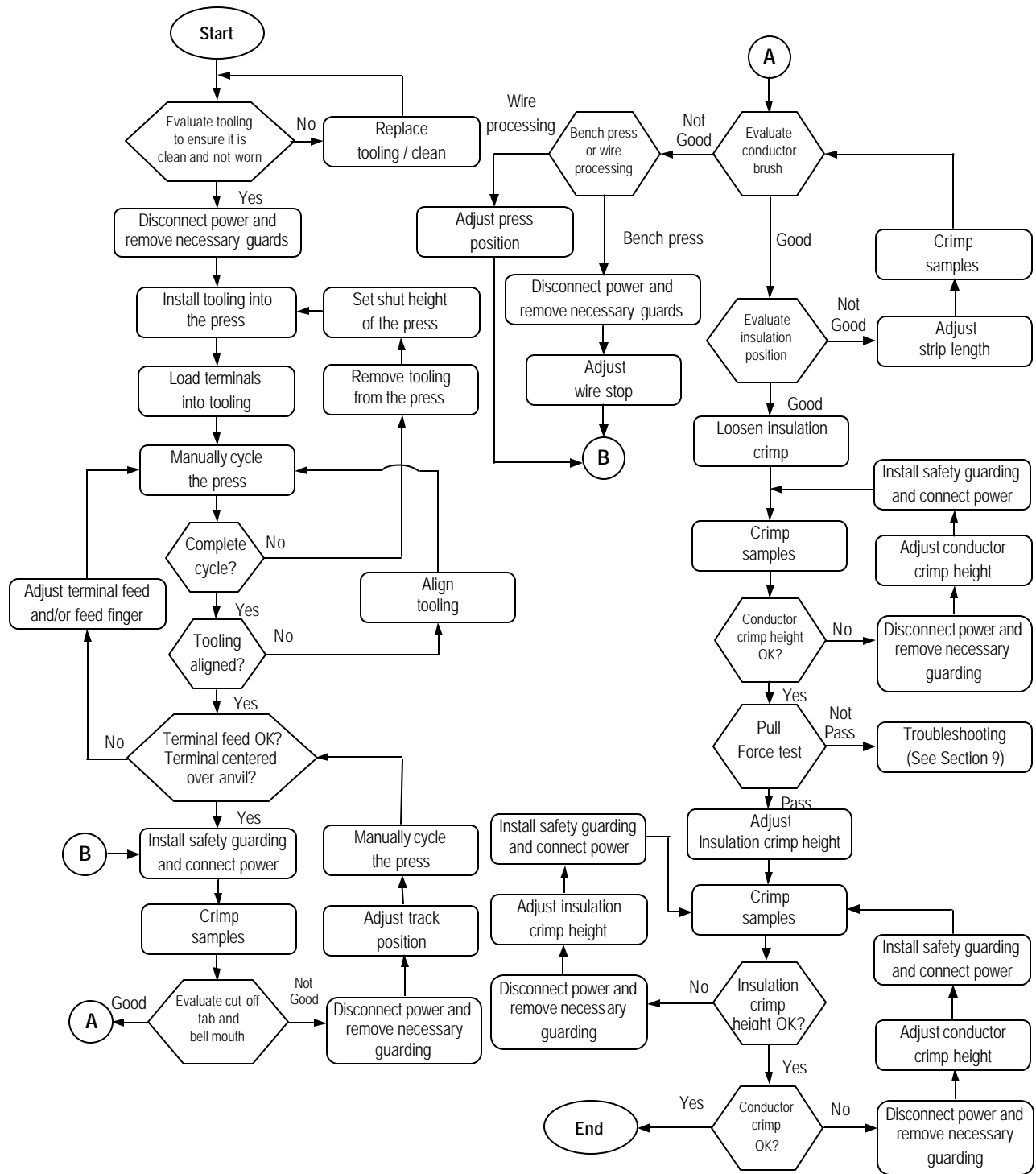
PROCEDURES

Tool Setup (Reference Procedures Flow Chart)

1. Check that tooling is clean and not worn. If necessary, clean and replace worn tooling.
2. Disconnect power to the press and remove guarding devices.
3. Install the appropriate tooling into the press.
4. Load terminals into the tooling so that the first terminal is located over the anvil.
5. Manually cycle the press to help ensure a complete cycle can be made without interference. If it cannot, remove tooling and check press shut height. Go to procedure 3.
6. Check that the tooling is aligned. Check the impression on the bottom of the crimp that was made by the anvil tooling. Check that the extrusions and crimp form are centered. If not, align tooling and go to procedure 5.
7. Check that the terminal feed locates the next terminal over the center of the anvil tooling. If not, adjust terminal feed and feed finger and go to procedure 5.
8. Re-install all safety devices that were removed during the set-up. **(Follow all safety requirements listed in individual press and/or tooling manuals.)**
9. Crimp sample terminals under power.
10. Evaluate cut-off tab length and conductor bell mouth. If adjustment is necessary, disconnect power to the press and remove guarding. Adjust track position. Manually cycle the press and check the feed finger for feed location, go to procedure 7.
11. Evaluate conductor brush. If adjustment is necessary, disconnect power to the press and remove guarding. Adjust wire stop for bench applications or press position on automatic wire processing equipment. Go to procedure 8.
12. Evaluate insulation position. If necessary, adjust strip length, crimp new samples, and go to procedure 11.
13. Loosen insulation crimp height.
14. Crimp sample terminals.
15. Measure conductor crimp height and compare to specification. If necessary, disconnect power and remove guarding. Adjust conductor crimp height, install guards, connect power, and go to procedure 14.
16. Perform a pull force test. Refer to troubleshooting (Section 9) if this test fails.
17. Adjust insulation crimp.
18. Crimp sample terminals.
19. Evaluate insulation crimp. If necessary, disconnect power and remove guarding. Adjust insulation crimp height, install guards, connect power, and go to procedure 18.
20. Measure crimp height and compare to specification. If necessary, disconnect power and remove guarding. Adjust conductor crimp height, install guards, connect power, and go to procedure 18.
21. Document measurements.

Please Work Safely At All Times.

PROCEDURES FLOW CHART



SECTION 7

MEASUREMENT

Pull Force Testing

1. Cut wire length to approximately 150mm (6") long.
2. Strip one end to 13mm (.50"), or long enough so no wire insulation is under the insulation grip, or loosen the insulation crimp so it has no grip on the insulation of the wire.
3. Terminate the appropriate terminal to the wire to the nominal crimp height.
4. Visually inspect the termination for bell mouth, wire brush and cut strands.
5. Set pull tester to 25.4mm per minute (1.00" per minute). For most applications, a higher rate will not have a significant impact on the data. The slower rate prevents a sudden application of force or jerking that snaps strands. Verify higher pull rates with data taken at 1.00" per minute.
6. If necessary, knot the un-terminated end of the wire (If insulation slips on wire).
7. Regardless of pull tester type, both wire and terminated end must be securely clamped. (Note: Clamp terminal contact interface, do not clamp conductor crimp)
8. Activate pull test.
9. Record pull force readings. A minimum of five pull force measurements should be done to confirm each set-up. A minimum of 25 readings should be taken for determining process capability.
10. Compare lowest reading to minimum pull force specification.

Note: High variability and lower value of C_{pk} (see section 8 for explanation of C_{pk}) are common when two wires are crimped together. The variability is due to more variation in conductor brush, conductor bell mouth and fewer strands of one wire being in contact with the serrations on the terminal barrel. A double wire crimp is considered no better than the smallest wire crimped. Higher pull force readings can be seen if both wires are gripped and pulled exactly together. Pulling each wire individually will result in a much lower pull force reading. If both wires are of the same size, the top wire will normally result in a lower reading

than the bottom wire due to the effects of the terminal serrations.

Wire Chart

Note: Pull force has only a minimum specification. For C_{pk} calculations, the average reading is assumed nominal and the upper specification limit is set so C_p and C_{pk} are equal. High pull force readings that increase the standard deviation can lower C_{pk} even if the mean and lowest reading are increased.

Test Values for Pull Force Test			
UL486A			
Size of Conductor		Pullout Force*	
AWG	mm ²	Lbf	N
30	0.05	1.5	6.7
28	0.08	2	8.9
26	0.13	3	13.4
24	0.20	5	22.3
22	0.324	8	35.6
20	0.519	13	57.9
18	0.823	20	89.0
16	1.31	30	133.5
14	2.08	50	222.6
12	3.31	70	311.5
10	5.261	80	356.0
8	8.367	90	400.5

*Consult individual specifications

Crimp Height Testing

1. Complete tool set-up procedure.
2. Crimp a minimum of five samples.
3. Place the flat blade of the crimp micrometer across the center of the dual radii of the conductor crimp. Do not take the measurement near the conductor bell mouth.
4. Rotate the micrometer dial until the point contacts the bottom radial (curved) surface. If using a caliper, be certain not to measure the extrusion points of the crimp.
5. Record crimp height readings. A minimum of five crimp height readings is necessary to confirm each set-up. A minimum of 25 readings should be taken for determining process capability.
6. Check crimp height every 250 to 500 parts throughout the run.

Note: Crimp height is usually control charted because it is a quick, nondestructive measurement and is critical for the termination's electrical and mechanical reliability. There are three primary purposes for control charting. One, the number of setup samples is normally small, and its statistical value is limited. Two, since special cause/effects on a process are irregular and unpredictable; it is necessary to have a means of catching changes in the process as soon as they occur. This prevents having to scrap thousands of terminations after the run is over. Three and this is most important, the data is necessary to assess and improve the crimp process.

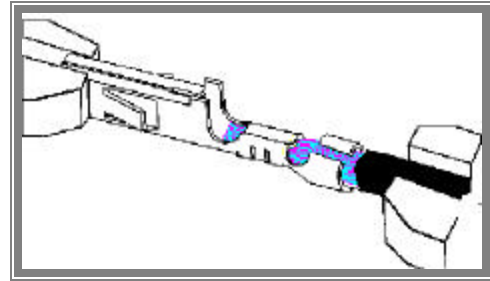


Figure 7-1
PULL TESTING

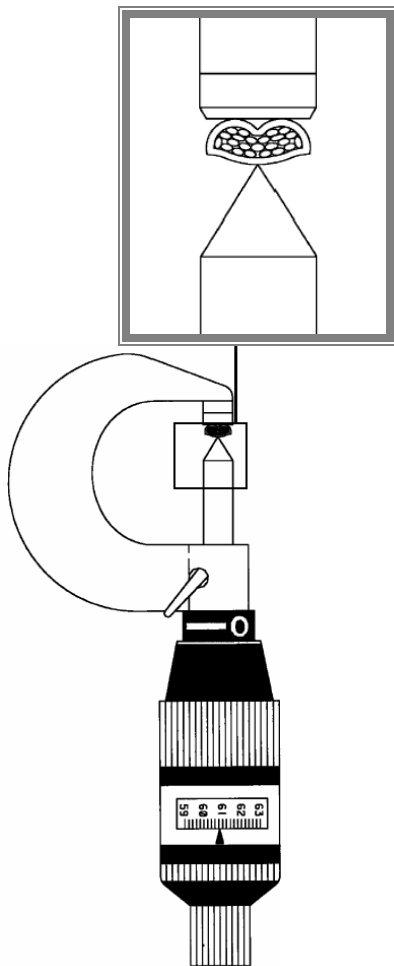


Figure 7-2
CRIMP HEIGHT MEASUREMENT
WITH A CRIMP MICROMETER

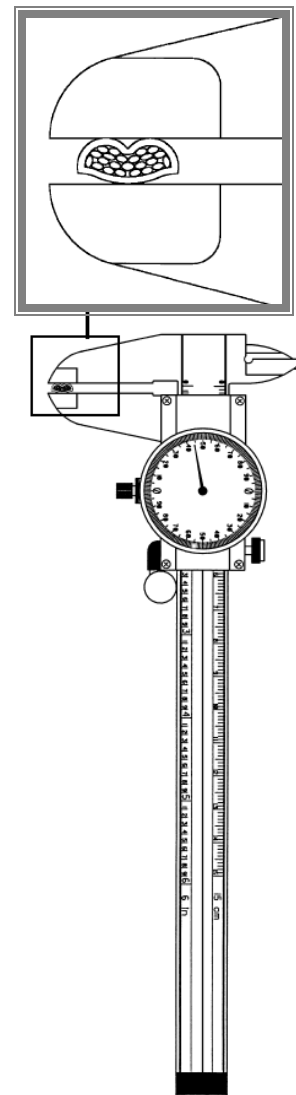


Figure 7-3
CRIMP HEIGHT
MEASUREMENTS WITH A
CALIPER

SECTION 8

CRIMP PROCESS CONTROL

The crimp process is the interaction of a terminal, wire, tooling, personnel, methods and procedures, and environmental attributes. When this process is controlled, it will produce a quality termination. Quality control is an important part of quality crimping. It should not take excessive setup or inspection time to do, and it can save a harness manufacturer thousands of dollars in potential rework or re-manufacturing.

Variability is the slight change that occurs from crimp to crimp. There are two types of variability, common or special. Common causes of variation affect the process uniformly and are the result of many small sources. Common variability is inherent tolerances within a reel of wire or terminals. Common variability also is created by the natural tolerances of the stripping and crimping machines.

Reducing variability at the common level typically has to come from changes to the wire, terminal, and tooling manufacturer.

Special causes of variation occur irregularly and unpredictably. Without checks throughout a run, having a tool become loose after the first hundred crimps or a jam resulting from a damaged tool may be undetected until thousands of crimps are made.

Process Capability

Before putting a new crimping tool in production, Molex recommends that each customer do a capability study, using the specific wire that will be used in its process. A capability study, which is based on the assumption of a normal distribution (bell-type curve), estimates the probability of a measurement being outside of specification.

Capability			
C _{pk}	+/- Sigma	% Yield	PPM*
0.67	2	95.45	45,500
1	3	99.73	2,699
1.33	4	99.99	63
1.67	5	99.99+	0.57
2	6	99.99++	0

* PPM - Parts Per Million (potential defects).

A 25 piece minimum sample needs to be taken from the crimping process. Calculate the average and standard deviation for the sample. A capability index is defined by the formula below. C_p may range in value from zero to infinity, with a larger value indicating a more capable process. A value greater than 1.33 is considered acceptable for most applications. C_p is calculated with the following formula.

$$C_p = \frac{\text{Tolerance}}{6 * \text{Standard Deviation}}$$

The C_{pk} index indicates whether the process will produce units within the tolerance limits. C_{pk} has a value equal to C_p if the process is centered on the mean of specification; if C_{pk} is negative, the process mean is outside the specification limits; if C_{pk} is between 0 and 1 then some of the 6 sigma spread falls outside the tolerance limits. If C_{pk} is larger than one, the 6-sigma spread is completely within the tolerance limits. C_{pk} is calculated with the lesser of the following formulas:

$$C_{pk} = \min \left(\frac{USL - \text{Mean}}{3 * \text{Standard Deviation}}, \frac{\text{Mean} - LSL}{3 * \text{Standard Deviation}} \right)$$

USL = Upper Specification Limit, LSL = Lower Specification Limit

Six sigma is a goal of many companies because it represents virtually zero defects. The ability of a company to achieve a six-sigma level depends on the amount of common variability in its process. For example, hand stripping the wire produces more variability than a stripping machine; crimping hand tools produce more variability than a press and die set, and bench terminations produce more variability than a wire-processing machine.

A part of the variability in crimping will result from the type of instruments that are used to measure the parts and the operator's ability to repeat the measurement. A crimp micrometer will measure more accurately than a dial caliper. An automatic pull force system will measure better than a hook type scale. It is important that the measurement gauge has enough resolution.

Two operators may measure the same part differently, or the same operator may measure the part differently when using two types of gauges. Molex recommends a gauge capability study to identify what part of the variability is coming from measurement error. Micro-terminals crimped to small wire sizes need a tight crimp height range to maintain pull force. The variability from measurement error can keep C_{pk} values low.

The capability of the crimping tools needs to be re-confirmed if the production data is significantly different from the capability study.

Production

Before the tool is ready for production, the level of capability needs to be established. Many harness manufacturers run only a few hundred or few thousand wires at one time. In this case, it is not practical or economical to run a twenty-five-piece capability with every set-up.

Visual Inspection

It needs to be standard operating procedure for the operator to manually fan each bundle of crimped wires and visually check bell mouth, conductor brush, insulation position, cut-off tab length, and insulation crimp.

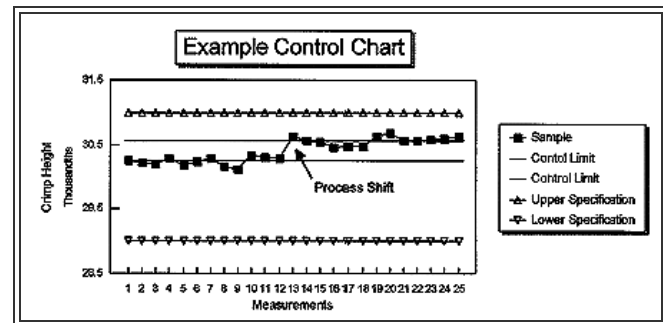
Control Charting

Crimp height is typically control charted because it is a quick nondestructive measurement and is critical for the termination's electrical and mechanical reliability. There are three primary purposes for control charting. One, the number of setup samples is usually small, with limited statistical value. Two, since special cause effects on a process are irregular and unpredictable; it is necessary to be able to catch changes in the process as soon as they occur. This prevents thousands of terminations from being scrapped after the run is over. Three, and most important, this data is necessary to assess and improve the crimp process.

Once the tooling process is setup and the wire size does not change, keep one control chart for wire color changes, wire length changes, terminal material

changes, or setup adjustments. Record the data point on the chart before making a crimp height adjustment. If data is recorded after each adjustment, the process is likely to assume control and provide little data for improving the process. The operator needs to make as many notes as possible on the chart. The only truly effective and economically sensible way to manage a manufacturing process is to understand, monitor and reduce sources of variability that are inherent to the process itself. Every minute required for setup or adjustments is unproductive.

What does this sample chart tell us?



X and R Chart

$$\text{Control limit for sample of } 5 = \text{Avg} (\text{Avg of 5 readings}) + .577 \times \text{Avg (Ranges)}$$

It indicates that a process shift occurred between measurement 12 and 13. This type of shift could occur due to a change in wire, a change in terminal lots, a jam in the machine that damaged the tooling, a change in operators, or an adjustment to the insulation crimp. Since the measurements are still within specification, would you stop production to adjust crimp height?

A shift in the process due to a change in material may warrant a crimp height adjustment. A shift after a jam would not indicate an adjustment, but a close evaluation of the tooling. A shift in the process between operators would not indicate an adjustment, but an evaluation of measurement capability. The purpose of a control chart is to identify what caused the shift in process to determine if an adjustment to the process is needed.

SECTION 9

TROUBLESHOOTING

Wire Preparation

Symptom	Cause	Solution
Irregular insulation cut (Figure 9-1)	Worn tooling	Replace tooling
	Wire cut depth too shallow	Adjust cut depth
Cut or nicked strands (Figure 9-2)	Damaged tooling	Replace tooling
	Cut depth too deep	Adjust cut depth
	Conductor not on wire center	Contact wire supplier
Irregular conductor cut/pulled strands (Figure 9-3)	Worn tooling	Replace tooling
	Wire cut depth too shallow	Adjust cut depth
Wire length variability too high (Figure 9-4)	Wire drive rollers/belts worn	Replace belts/rollers
	Insulation durometer too hard	Increase drive pressure
	Wire straightener too loose or tight	Adjust wire straightener
Wrong strip length (Figure 9-4)	Incorrect setup	Re-setup tooling

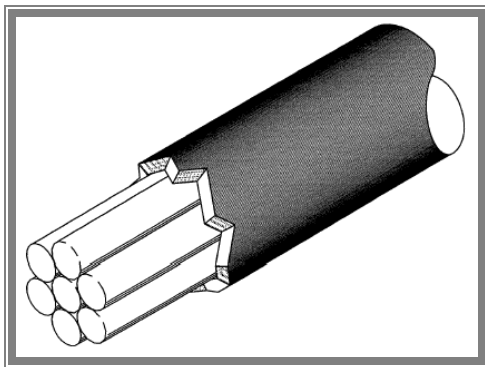


Figure 9-1
IRREGULAR INSULATION CUT

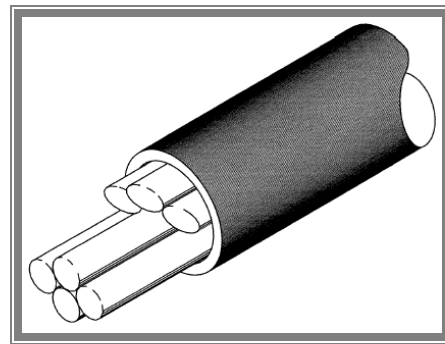


Figure 9-2
CUT STRANDS

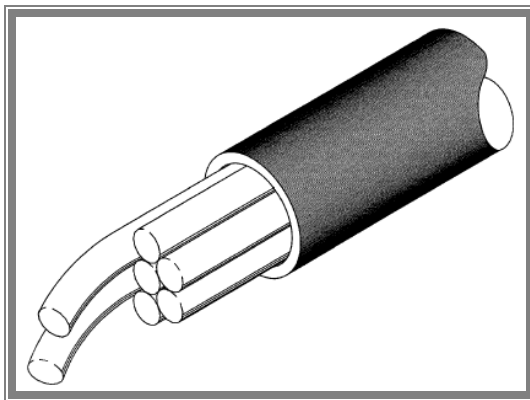


Figure 9-3
PULLED STRANDS

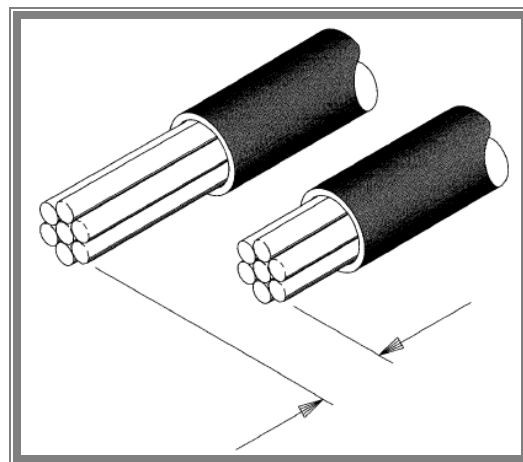
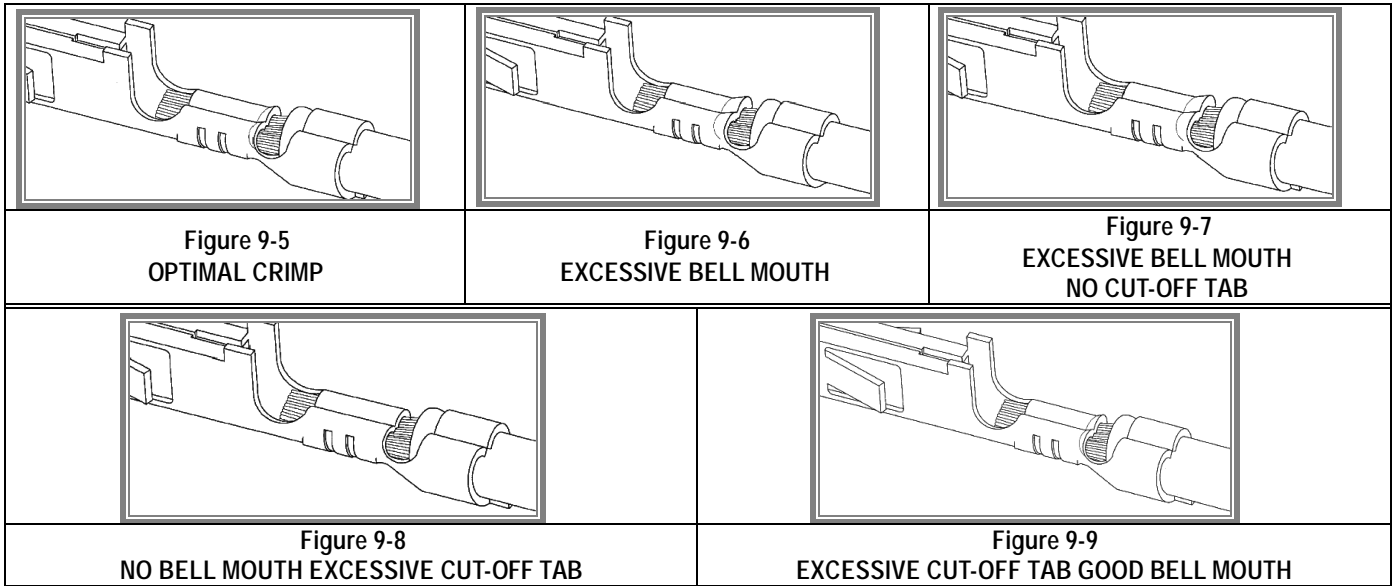


Figure 9-4
WIRE LENGTH VARIABILITY OR WRONG STRIP LENGTH

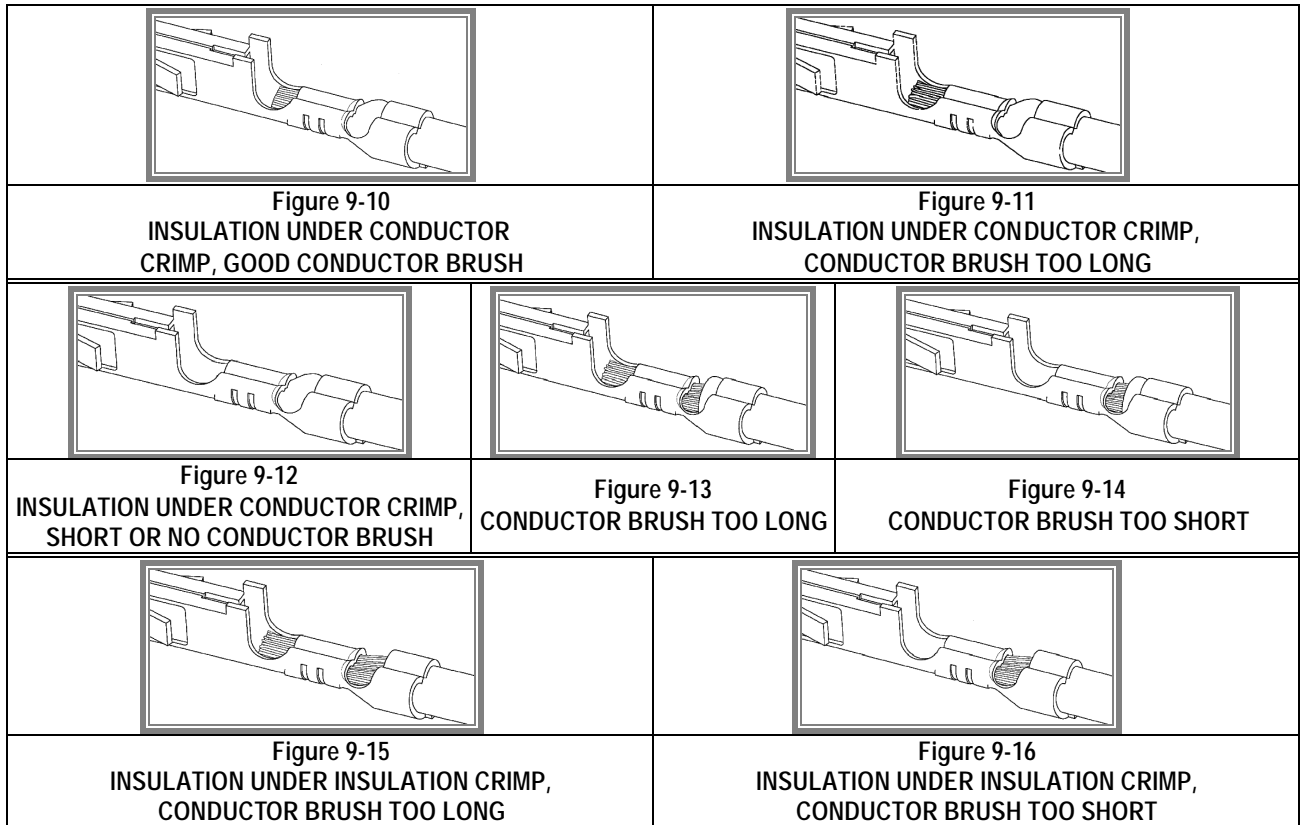
Bell Mouth and Cut-off Tab Length

Symptom	Cause	Solution
Low pull force (Figure 9-6 and 9-7)	Excessive bell mouth, no cut-off tab	Adjust track position for small cut-off tab
	Excessive bell mouth, cut-off tab alright	Check for worn or incorrect punch tooling and replace
Cut or nicked strands (Figure 9-8)	No bell mouth and/or excessive cut-off tab	Adjust track position
		Check for camber in terminal strip
Long cut-off tab (Figure 9-9)	Good bell mouth and excessive cut-off tab	Check for worn cut-off and replace if necessary
		Check for worn punch tooling, replace, and re-adjust track



Conductor Brush and Insulation Position

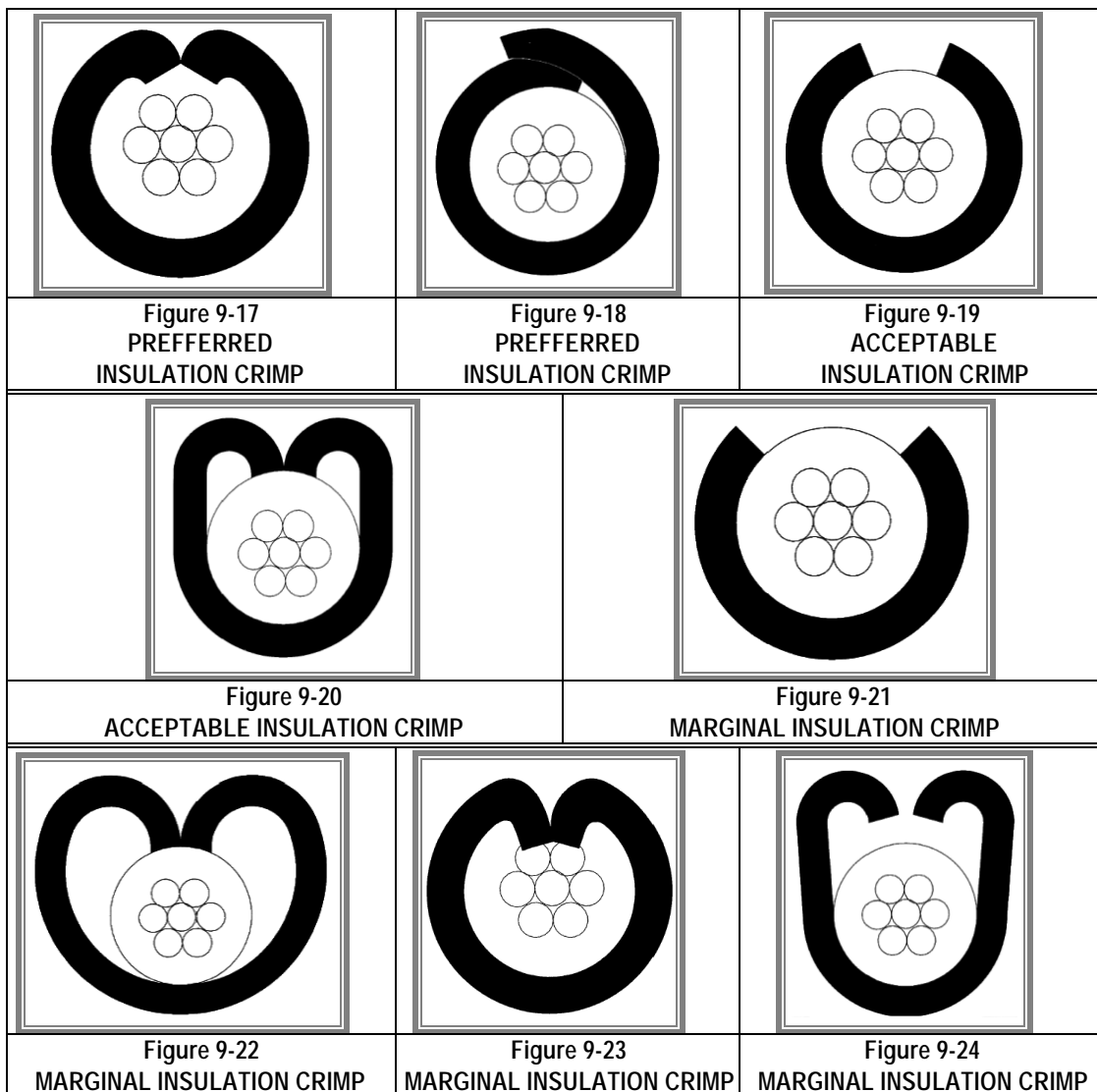
Symptom	Cause	Solution
Insulation under conductor crimp, good conductor brush (Figure 9-10)	Strip length too short	Check specification, adjust strip length longer
Insulation under conductor crimp, long conductor brush length (Figure 9-11)	Bench top crimping - Wire stop position incorrect	Adjust wire stop to center of transition area
	Wire Processing - Press position incorrect	Adjust press position away from wire
Insulation under conductor crimp, short or no conductor brush (Figure 9-12)	Strip length too short	Check specification, adjust strip length longer
		Re-adjust wire stop position for bench top applications OR re-adjust press position for wire processing applications
Insulation edge centered in transition area, conductor brush too long (Figure 9-13)	Strip length too long	Check specification, adjust strip length shorter
		Re-adjust wire stop position for bench top applications OR re-adjust press position for wire processing applications
Insulation edge centered in transition area, conductor brush too short (Figure 9-14)	Strip length too short	Check for worn stripping tooling
		Check specification, adjust strip length longer
Insulation edge under insulation crimp, Good or long conductor brush (Figure 9-15)	Strip length too long	Re-adjust wire stop position for bench top applications OR re-adjust press position or wire processing applications
		Check specification, adjust strip length shorter
Insulation edge under insulation crimp, short or no conductor brush (Figure 9-16)	Bench top crimping - Wire stop position incorrect	Adjust wire stop to center of transition area
	Wire processing - Press position incorrect	Adjust press position away from wire
	Verify operators wire placement ability	Operator training, reduce crimping rate



Insulation Crimp

Symptom	Cause	Solution
Terminal surrounds less than 88% of a large diameter wire (Figure 9-21)	Crimp too loose, not enough terminal insulation barrel	Tighten insulation crimp height Evaluate terminal
Terminal contacts less than 50% of a small diameter wire (Figure 9-22)	Too much terminal insulation barrel	Evaluate terminal
Insulation crimp barrels cut through insulation into conductor strands (Figure 9-23)	Crimp too tight	Adjust insulation crimp height*
Insulation not firmly gripping insulation, fails bend test (Figure 9-24)	Crimp too loose	Adjust insulation crimp height tighter

* Inexpensive hand tools provide no adjustment for the insulation crimp. A hand tool is intended for low volume applications. Although you are not able to adjust the insulation crimp on a hand tool, an insulation crimp, which pierces the insulation, may still be considered acceptable for many applications. This criterion only applies to hand tools due to their low speed crimp cycle. If the insulation crimp pierces the insulation, the wire strands tend to move aside without damage.



Crimp Height

Symptom	Cause	Solution
Crimp height off target (Figure 9-26)	Changed wire type vendor or stranding	Adjust tooling back to target
	Changed insulation color or durometer	
	Changed crimp tooling	
	Changed crimp press (shut height)	
	Changed press type (manufacturer)	
	Changed terminal reel (lot code)	
	Changed tooling set-up	
Crimp height variability too high (Figure 9-27)	Damaged or worn tooling	Replace tooling
	Wire variability	Inspect incoming product
	Terminal variability	
	Damaged, loose or worn tooling	Tooling replacement or tightening
	Measurement error	Gauge capability analysis
	Terminal spring-back too great, over crimping	Crimp height adjustment
Cut or missing wire strands	Stripping process adjustment	

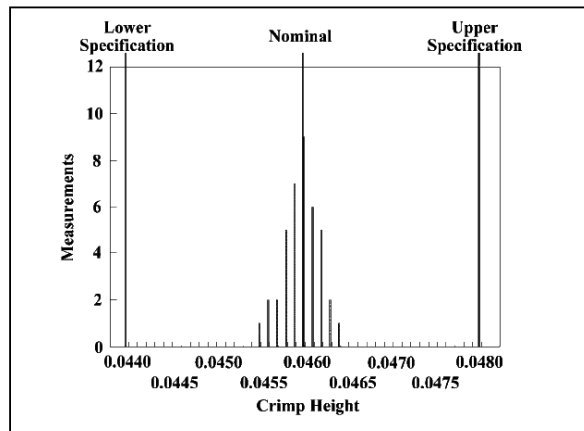


Figure 9-25
OPTIMAL CRIMP HEIGHT CHART

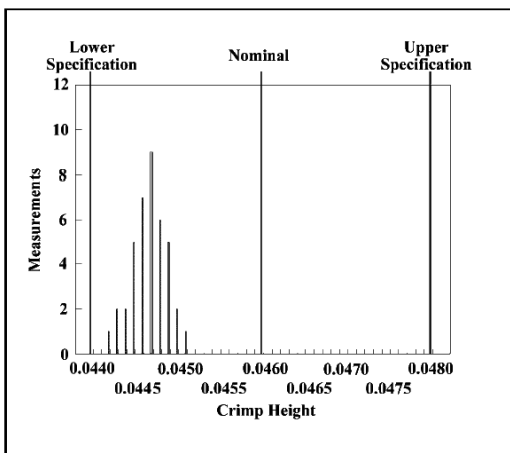


Figure 9-26
CRIMP HEIGHT OFF TARGET

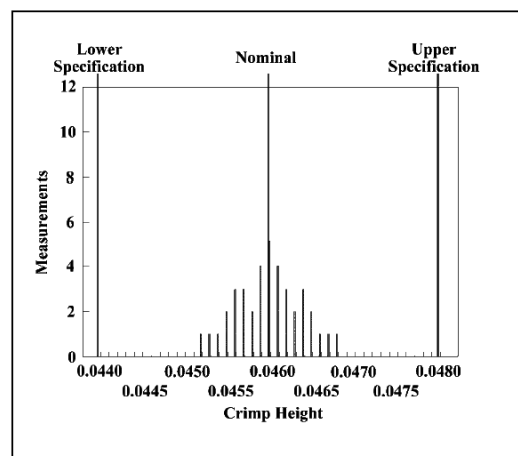


Figure 9-27
CRIMP HEIGHT VARIABILITY TOO HIGH

Pull Force

Symptom	Cause	Solution
Wire breaks before conductor crimp - low pull force (Figure 9-29)	Cut or nicked strands	Check the stripping process
	Crimp height too low	Adjust crimp height
	Small or no bell mouth	Adjust tooling track
	Insulation crimp through insulation wall	Raise insulation crimp height
Wire pulls out of conductor grip - low pull force (Figure 9-29)	Crimp height too high	Adjust crimp height
	Small or no conductor brush	Increase strip length
	Conductor bell mouth too big	Adjust tooling track
	Gold terminal application	Evaluate the terminal application
	Terminal material thickness too small	
	Light serrations on terminal	Contact your local sales engineer

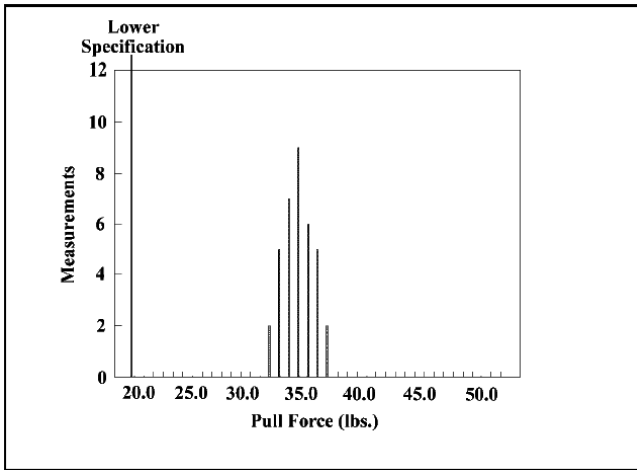


Figure 9-28
OPTIMAL PULL FORCE CHART

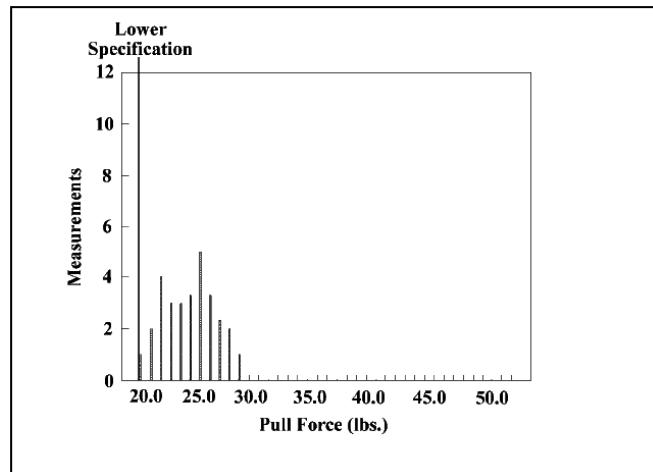


Figure 9-29
LOW PULL FORCE CHART

SECTION 10

WIRE GAUGE CHART

AWG	Wire Area		Stranding		Wire Diameter		Circular	Wire Break	
	Sq. mm	Sq. inch	No.	Dia.	mm	In.	Mills	N	Lbf.
8	8.302	.01287	1	.1280	3.25	.128	16384	2175.00	489.0
8	7.820	.01212	19	.0285	3.68	.145	15433	2048.72	460.6
8	7.955	.01233	49	.0179	3.73	.147	15700	2084.21	468.6
8	8.605	.01334	133	.0113	3.73	.147	16983	2254.49	506.9
8	8.513	.01319	168	.0100	3.73	.147	16800	2230.22	501.4
8	8.424	.01306	665	.0020	3.73	.147	16625	2206.99	496.2
10	5.261	.00816	1	.1019	2.59	.102	10384	1378.44	309.9
10	4.740	.00735	37	.0159	2.92	.115	9354	1241.75	279.2
10	5.006	.00776	49	.0142	2.95	.116	9880	1311.63	294.9
10	5.320	.00825	105	.0100	2.95	.116	10500	1393.89	313.4
12	3.308	.00513	1	.080	2.05	.081	6529	866.69	194.8
12	3.632	.00563	7	.0320	2.44	.096	7168	951.56	213.9
12	3.085	.00478	19	.0179	2.36	.093	6088	808.16	181.7
12	3.294	.00511	65	.0100	2.41	.095	6500	862.88	194.0
12	3.3118	.00514	165	.0063	2.41	.095	6549	869.37	195.5
14	2.082	.00323	1	.0641	1.63	.064	4109	545.45	122.6
14	2.270	.00352	7	.0253	1.85	.073	4481	594.81	133.7
14	1.941	.00301	19	.0142	1.85	.073	3831	508.59	114.3
14	2.078	.00322	41	.0100	1.85	.073	4100	544.28	122.4
14	2.112	.00327	105	.0063	1.85	.073	4167	553.24	124.4
16	1.308	.00203	1	.0508	1.30	.051	2581	342.58	77.0
16	1.433	.00222	7	.0201	1.52	.060	2828	375.43	84.4
16	1.229	.00191	19	.0113	1.47	.058	2426	322.07	72.4
16	1.317	.00204	26	.0100	1.50	.059	2600	345.15	77.6
16	1.307	.00203	65	.0063	1.50	.059	2580	342.48	77.0
16	1.330	.00206	105	.0050	1.47	.058	2625	348.47	78.3
18	.823	.00128	1	.0403	1.02	.040	1624	215.60	48.5
18	.897	.00139	7	.0159	1.22	.048	1770	234.93	52.8
18	.811	.00126	16	.0100	1.19	.047	1600	212.40	47.8
18	.963	.00149	19	.0100	1.24	.049	1900	252.23	56.7
18	.825	.00128	41	.0063	1.19	.047	1627	216.03	48.6
18	.823	.00128	65	.0050	1.19	.047	1625	215.72	48.5
20	.519	.00080	1	.0320	.81	.032	1024	135.94	30.6
20	.563	.00087	7	.0126	.97	.038	1111	147.53	33.2
20	.507	.00079	10	.0100	.89	.035	1000	132.75	29.8
20	.616	.00096	19	.0080	.94	.037	1216	161.43	36.3
20	.523	.00081	26	.0063	.91	.036	1032	136.99	30.8
20	.519	.00081	41	.0050	.91	.036	1025	136.07	30.6
22	.324	.00050	1	.0253	.64	.025	640	84.97	19.1
22	.355	.00055	7	.0100	.76	.030	700	92.93	20.9

AWG	Wire Area		Stranding		Wire Diameter		Circular	Wire Break	
	Sq. mm	Sq. inch	No.	Dia.	mm	In.	Mills	N	Lbf.
22	.382	.00059	19	.0063	.79	.031	754	100.11	22.5
22	.329	.00051	26	.0050	.76	.030	650	86.29	19.4
24	.205	.00032	1	.0201	.61	.024	404	53.63	12.1
24	.227	.00035	7	.0080	.58	.023	448	59.47	13.4
24	.201	.00031	10	.0063	.61	.024	397	52.69	11.8
24	.241	.00037	19	.0050	.58	.023	475	63.06	14.2
24	.200	.00031	41	.0031	.58	.023	394	52.31	11.8
26	.128	.00020	1	.0159	.40	.016	253	33.56	7.5
26	.141	.00022	7	.0063	.53	.021	278	36.88	8.3
26	.127	.00020	10	.0050	.51	.020	250	33.19	7.5
26	.154	.00024	19	.0040	.48	.019	304	40.36	9.1
28	.080	.00012	1	.0126	.32	.013	159	21.08	4.7
28	.089	.00014	7	.0050	.38	.015	175	23.23	5.2
28	.093	.00014	19	.0031	.41	.016	183	24.24	5.4
30	.051	.00008	1	.0100	.25	.010	100	13.28	3.0
30	.057	.00009	7	.0040	.30	.012	112	14.87	3.3
30	.060	.00009	19	.0025	.30	.012	118	15.64	3.5
32	.032	.00005	1	.0080	.20	.008	64	8.50	1.9
32	.034	.00005	7	.0031	.20	.008	67	8.93	2.0
32	.039	.00006	19	.0020	.23	.009	76	10.09	2.3

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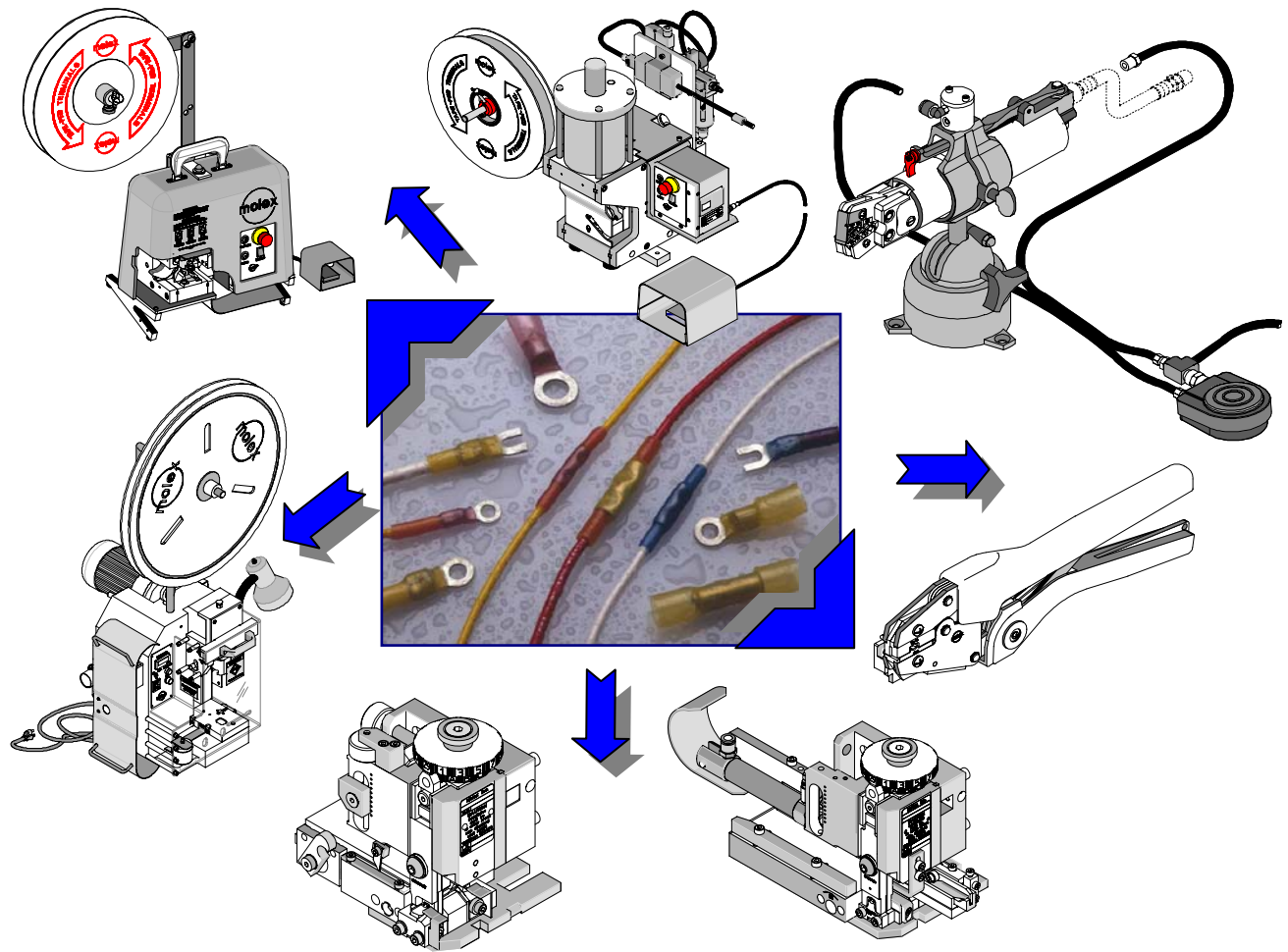
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**INDUSTRIAL CRIMP QUALITY
HANDBOOK
Order No. 64016-0065**

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SECTION 1

INTRODUCTION TO CRIMP TECHNOLOGY

Developed to replace the need to solder terminations, crimping technology provides a high quality connection between a terminal and a wire at a relatively low applied cost. The methods for applying crimp terminations depend on the application, volume, and range from hand-held devices to fully automated systems.

The application methods include a basic hand tool, a press and die set, a stripper crimper, or a fully automatic wire processing system. However, no matter what method is used, the setup of each tool is critical for achieving a quality crimp.

Today, many OEM companies are using Statistical Process Control (SPC) to continuously improve their crimp terminations. Crimp termination is a complex process and to ensure consistent quality it is necessary to understand the variability and inter-relational interactions that the technology involves.

Without a thorough understanding of the crimping process, and all the factors that can affect it, the result may not meet expectations. The three key elements in the crimping process are the terminal, the wire, and the tooling.

Terminal

For most applications, it is not economically practical for connector manufacturers to design a terminal to accept one wire size, one wire stranding, and one insulation diameter (UL type) as well as Mil Specification. Most terminals accommodate many wire sizes, stranding, and a range of insulation diameters, and the terminals are designed to meet acceptable levels over this entire range.

Wire

The wire stranding and insulation type can vary widely within one wire size. For example, there is more than 18% more material in an 18 AWG by 19-strand wire than an 18 AWG by 16-strand wire. The insulation diameter of an 18 AWG wire can range from 1.78mm (.070") to over 4.57mm (.180"). Wire strands can be copper, tinned, over coated, or top coated. Wire insulation materials, thickness, and durometers vary from application to application.

Tooling

What type of tooling does the application require? Does the application require hand stripping of the wire or does the volume dictate an automatic wire-stripping machine? Does the application and volume require hand tools, press and die, or fully automatic wire process machines? Crimping with a manual hand tool, semi-automatic press and die, or fully automatic wire processor, all involve different levels of variability. The terminal, wire, and type of application tooling all affect the quality of the completed terminations.

SECTION 2

PURPOSE AND SCOPE

Purpose

This handbook provides general guidelines and procedures for understanding and achieving acceptable crimp terminations. A glossary in Section 3 lists common terms and definitions. Section 4 lists the tools that are necessary to take accurate measurements and evaluate the crimp's acceptability.

For open barrel only, the tooling setup is critical in determining the quality of the finished crimp. The attributes that need to be considered include crimp height, conductor brush, bell mouth, cut-off tab and strip length and insulation position. Variability in one or more of these attributes can reduce the measured pull force. It can be difficult to establish acceptable variability limits because the attributes all interact with one another.

For example, a track adjustment for bell mouth also will change the cut-off tab length and the insulation wire position while strip length and wire locations affect the conductor brush and insulation position. Adjusting the insulation crimp height may result in a slight change to the conductor crimp height measurement. It may be necessary for the setup person to make multiple adjustments to establishing an optimal setup.

The order in which a setup is done may help reduce the number of repetitions required for an optimum setup.

This handbook is structured so that parts, or all, of its contents can be used as a procedural guide for ISO requirements.

Scope

This handbook is intended for Molex customers who are crimping Molex open and closed barrel crimp terminals and are using Molex tooling.

The handbook's contents may slightly differ from other connector manufacturers' or individual company guidelines and procedures.

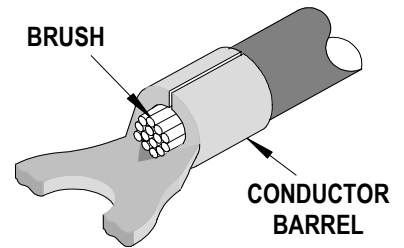
This handbook provides a basic overview of what to look for in an acceptable crimp. It is not intended to replace individual product and/or tooling specifications.

Individual terminals or applications may have special requirements. Tooling limitations also may not permit an attribute to be adjusted to meet optimum requirements.

SECTION 3

DEFINITIONS AND TERMS

- **AWG**
Acronym for American Wire Gauge. It is the most popular of many systems for designating single, round, solid, non-steel wire diameter in United States of America. Stranded wires are designated based on comparison of their total cross-sectional area of the conductor part only (their current carrying capacity) and cross-sectional area of a corresponding solid wire.
- **Barrel**
It is the back end portion of a terminal or contact. It is crimped to the conductor, insulation, or both. When designed to receive the conductor, it is called the conductor barrel. When designed to support or grip the insulation, it is called the insulation barrel.
- **Bell Mouth**
This is the undisturbed portion of the conductor barrel nearest the insulation crimp. It is the result from the actual crimping, which acts as a funnel for the wires and reduces the possibility of a sharp edge on the barrel cutting or nicking the wires.
- **Bend Test**
One way to test the insulation crimp is by bending the wire several times and then evaluating the movement of the insulation and wire strands. As a rule, the insulation crimp should withstand the wire being bent 60 to 90 degrees in any direction, several times. Use care when working with small wire sizes so the wire at the back of the insulation crimp does not shear.
- **Butt Splice**
It is a device to join two conductors, end-to-end, rather than overlapping.
- **Chamfer**
An angle on the inside edge of the barrel entrance of a terminal that permits easier insertion of the wires into the barrel.
- **Circular Mil (CM)**
A unit of area used to indicate wire size. It is the computed total cross sectional area of conductors. One circular mil equals cross-sectional area of a wire one mil (0.001 inches) in diameter.
CMA – acronym for Circular Mil Area
- **CMA**
Acronym for Circular Mil Area
- **Contact Area**
It is the area in contact between two conductors, or a conductor and a connector permitting the flow of electricity.
- **Conductor Brush**
The conductor brush is made up of the wire strands that extend past the conductor barrel on the contact side of the terminal. This helps ensure that mechanical compression occurs over the full length of the conductor crimp. The conductor brush should not extend into the contact area.



terminal plating, one crimp height specification is normally created.

*Consult individual terminal specification requirements.

■ **Crimp**

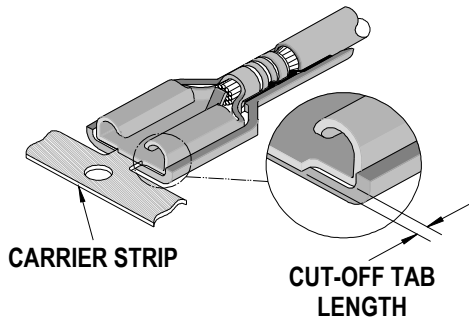
It is the act of physically compressing (forming) a connector or contact barrel around a cable in order to make an electrical connection. On a crimped terminal, a second crimp is often added to the insulation area for added strain relief.

■ **CSA**

Canadian Standards Association is an independent Canadian testing laboratory similar to UL (Underwriters Laboratories Inc.).

■ **Cut-off Tab Length**

This material protrudes outside the end of the terminal after the terminal is separated from the carrier strip. As a rule, the cut-off tab should be flush or .254mm (.010”) protruding outside the housing sleeve. A cut-off tab, which is too long, may expose a terminal outside the housing or it may fail electrical spacing requirements. In most situations, a tool is set-up to provide a cut-off tab that is flush to one material thickness.



■ **Dielectric Test**

A test that uses the application of a voltage higher than the rated voltage for a specific time for the purpose of determining the adequacy against breakdown of insulation materials and spacing under normal conditions. This test is used to ensure the crimping procedure did not puncture or destroy the insulation material on the terminal.

■ **Extrusions (Flash)**

These small flares form on the bottom wire barrel resulting from the clearance between the punch

and anvil tooling. If the anvil is worn or if the terminal is over-crimped an excessive extrusion results. An uneven extrusion may also result if the punch and anvil being misaligned.

■ **Ferrule**

A short tube used to mate solderless connectors to shielded or coaxial cable. It is used as an insulation grip sleeve on solderless terminals.

■ **Flash**

It is an abnormal protrusion on the wire barrel, (either insulation material or metal), which indicates that the crimping tool is either misaligned or worn and thus should not be used.

■ **Funnel Entry**

It is a crimped terminal or splice barrel, which opens to facilitate quick and easy wire insertion.

■ **Gas Tight Seal**

A contact system that utilizes soft metals at high contact pressures so that upon mating, metal is upset and the resultant joint prevents contaminant gases from entering the contact area.

■ **Gauge**

A method of measurement, often using “go” and “no-go” pins or shapes to determine if an attribute is within tolerance.

■ **Harness**

A group of wires or cables joined to form a circuit network for electronic or electrical equipment. A harness is usually an assembly of cables cut to the proper length, terminated, and tied together prior to being assembled in a piece of equipment.

■ **Insulation Crimp (Strain Relief)**

It is a crimp encompassing both the wire and insulation. This helps to prevent the conductor from being exposed due to the insulation receding and offers additional resistance to vibration.

■ **Insulation Crimp Height**

Molex does not specify insulation crimp heights because of the wide variety of insulation thickness, material, and hardness. Most terminals are designed to accommodate multiple wire ranges.

Within the terminal's range, an insulation grip may not completely surround the wire or fully surround the diameter of the wire. This condition will still provide an acceptable insulation crimp for most applications.

- ✓ A large insulation grip should firmly grip at least 88% of the wire.
- ✓ A smaller insulation grip should firmly grip at least 50% of the wire and firmly hold the top of the wire.

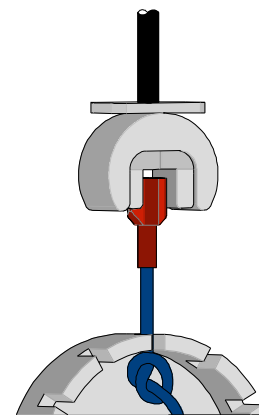
To evaluate the insulation section, cut the wire flush with the back of the terminal. Once the optimum setting for the application is determined, it is important to document the insulation crimp height. Then, as part of the setup procedure, the operator can check the insulation crimp height.

- **Locator**
A device for positioning terminals, splices, or contacts in crimping dies.
- **MCM (or kcmil)**
Unit of area, based on Circular Mil, equal to one thousand circular mils. Usually used instead of AWG above wire sizes greater than 4/0 AWG.
- **Mega (mega, M)**
Prefix denoting one million, e.g., one megavolt = one million volts.
- **Micro (micro, μ)**
Prefix denoting one millionth, e.g., one microvolt = one millionth of a volt.
- **Mil Spec**
Military Specification. A specification used for qualification of products for acceptability as required for U.S. Government applications (usually for a military branch), e.g. Mil-T-7928 covers terminals, lugs, splices, conductors, crimp style.
- **Mechanical Strength**
To insure how strong the connection is or how much the wire and terminal must be squeezed to get a gas tight seal. It's important to crimp the wires tight enough to keep them from slipping out of the connector, but not so tight as to crush the wires in

the terminal, causing them to break off. The connection is weakened if the wires are cut or nicked.

- **Nest**
The portion of a crimping die, which supports or reshapes the barrel during crimping.
- **PSI, psi**
(Pound-Force per Square Inch) Non-SI unit of pressure. Used mainly to denote pressure of air or other gas, e.g. 75 psi.
- **Pound-Force (lbf)**
Unit of force, 1lbf is approximately equal to force exerted on a mass of 1 lb by gravitational force of Earth at its surface, or a force exerted by that mass (stationary) on a support (i.e. if mass of 1 lb is hung on a wire, it exert a force of ca. 1 lbf (directed down) on that wire).
- **Pull Force Testing**
Pull force testing is a quick, destructive method to evaluate the mechanical properties of a crimp termination.

Pull force testing results out of allowed range are good indicators of problems in the process. Cut or nicked strands in the stripping operation, lack of bell mouth or conductor brush, or incorrect crimp height or tooling will reduce pull force. Wire properties and stranding, and terminal design (material thickness and serration design), also can increase, or decrease the value of the results of a pull force test.

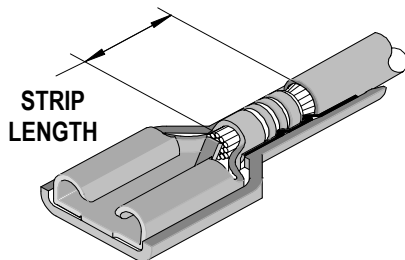


If results of a pull force tests are within an allowed range, it assures that proper crimp force has been applied during crimping. It is crucial as, when making a crimp, enough force must be applied to break down the layer of non-conductive oxides that may build up on the stripped conductor and the tin-plating on the inside of the terminal grip. This is necessary to provide a good metal-to-metal contact.

If this does not occur, resistance can increase. Over-crimping a crimp termination will reduce the circular area of the conductor and increase resistance.

- **Serrations**
It is the saw-toothed grooves on the surface of a terminal, which ensures firm gripping of the conductor. Also provides additional contact area.
- **Solderless**
This means without solder – in our case, denoting the use of a crimping tool.
- **Splice**
A device used to join two or more conductors together.
- **Strip Length**
The strip length is determined by measuring the exposed conductor strands after the insulation is removed. The strip length determines the conductor brush length when the insulation position is centered.

*Consult individual terminal specification requirements

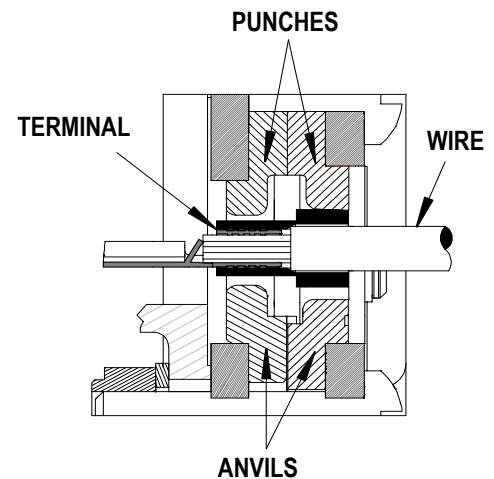


- **Tab**
Flat rectangular male connection tabs on electrical components; various sizes to fit female quick disconnects.
- **Tensile Test**
This is a pull test to determine the mechanical strength of the crimped wire. They are specific minimum values set for each wire size. See Section 8.
- **Terminal**
A device designed to terminate a conductor that is to be affixed to a wire or cable to establish an electrical

connection. It is a synonym for contact. There are two main types, which include the open barrel and the closed barrel. Parts of the terminal are:

- Insulation barrel Where the wire's insulation will be crimped or supported so that it is firmly gripped.
- Wire barrel Where the bare wire will be crimped.
- Contact area Where the terminal will be attached to the mating part.

- **Terminal Position**
The terminal position is set by the alignment of the terminal to the forming punch and anvils, and the carrier-strip cut-off tooling. The tool set-up determines conductor, cut-off tab length, and terminal extrusions.



- **UL**
Underwriters' Laboratories, Inc., founded in 1894, is chartered as a not-for-profit organization under the laws of Delaware, to establish, maintain, and operate laboratories for the investigation of materials, devices, products, equipment, construction methods, and systems with respect to hazards affecting life and property.
- **Voltage Drop Test**
A test of the voltage developed across a component or conductor being a result of electric current flow in the component or conductor and its non-zero electrical resistance. It is the test of the electrical integrity of the crimp.
- **Wire**
They are a group of conductors that has a low resistance to current flow, together with any

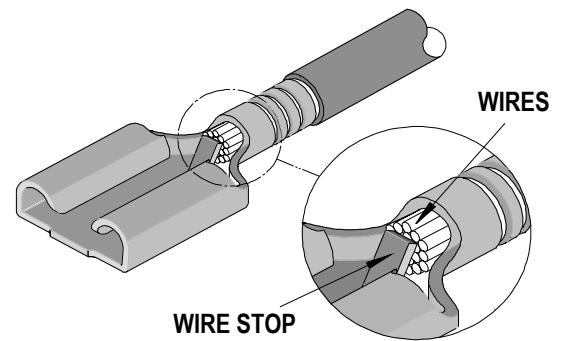
associated insulation. There are two kinds: a solid wire, which is one single strand of material, or stranded group of wire, which is a bundle of wires twisted together to act as one.

■ **Wire Size**

Wires have varying sizes or gauges that carry different amounts of electrical current with each wire used for a separate purpose. The size (in AWG) is called out with a number, such as 8 or 10, followed by the letters AWG, which stand for American Wire Gauge.

■ **Wire Stop**

It is a stop at the end of a terminal wire barrel. It prevents wire from passing completely through the barrel so the wire will not interfere with the function of the contact.

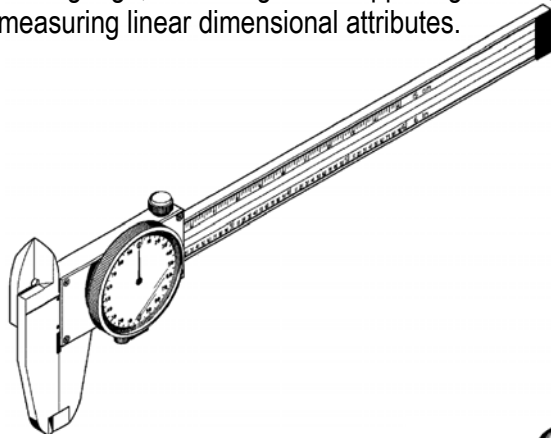


SECTION 4

ASSOCIATED MATERIALS

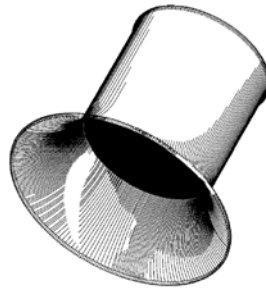
■ **Caliper**

It is a gauge, consisting of two opposing blades, for measuring linear dimensional attributes.



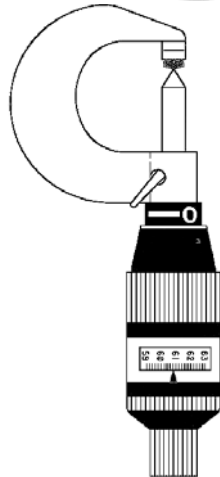
■ **Eye Loupe**

It is an image magnification tool, normally 10 times power or greater, which is used to aid visual evaluation of a crimp termination.



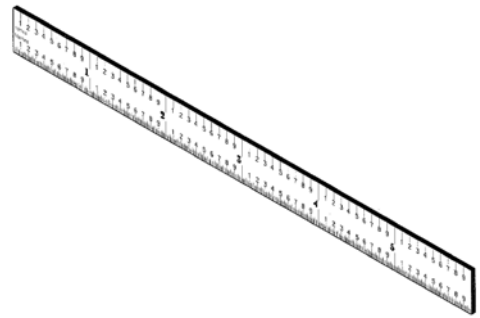
■ **Crimp Micrometer**

This is a micrometer specifically designed to measure crimp height. The measurement is taken in the center of the crimp so the conductor bell mouth does not influence it. It has a thin blade that supports the top of the crimp while a pointed section determines the bottom radial (curved) surface.



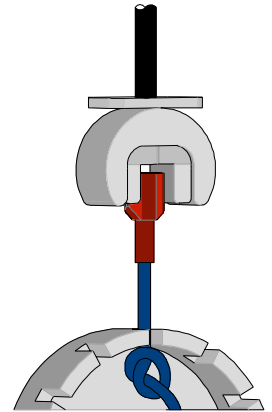
■ **Ruler (Pocket Scale)**

This is used to measure the length of bell mouth, cut-off tab, conductor brush, and strip length and estimate wire position. The recommended minimum resolution is 0.50mm (.020”).



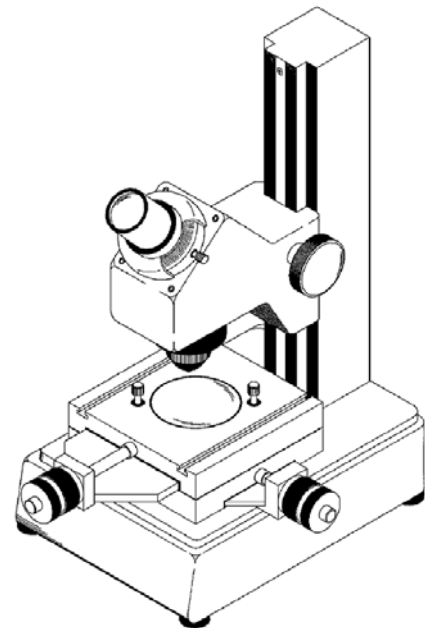
■ **Pull Tester**

A device used to determine the mechanical strength of a crimp termination. Most pull testing is done with a device that clamps the wire, pulls at a set speed, and measures force by means of a load cell. A pull tester also can be as simple as hanging fixed weights on the wire for a minimum of one minute.



■ **Toolmaker's Microscope**

This is used for close visual evaluation and statistical measurement of bell mouth, cut-off tab, conductor brush, wire position, and strip length.



SECTION 5

TERMINAL DESCRIPTION

5.1 Features of Solderless Terminals

The properties of the base material must be evaluated. The material (metal) is either copper or brass depending on the product.

- Molex base metals are purchased, inspected, and received to product specifications.
- Most of these terminals are applied the guidelines of UL; Underwriters Laboratories is a US organization that sets certain standards for connector testing.
- Some terminals use the guidelines of Mil-T-7928, set by the United States Government.

The following charts show the UL and US Government specifications (MIL-T-7928) for wire pull-out forces of various wire sizes. The tensile strength is shown in lbf (pound-force). It indicates the minimum acceptable force to break or separate the terminal from the conductor.

Color Code	Wire Size (AWG)	*UL - 486 A	*UL - 486 C	*UL - 310	*Military Class 2
Yellow	26	3	N/A	N/A	7
Yellow	24	5	N/A	N/A	10
Red	22	8	8	8	15
Red	20	13	10	13	19
Red	18	20	10	20	38
Blue	16	30	15	30	50
Blue	14	50	25	50	70
Yellow	12	70	35	70	110
Yellow	10	80	40	80	150
Red	8	90	45	N/A	225
Blue	6	100	50	N/A	300

*UL - 486 A - Terminals (Copper conductors only)

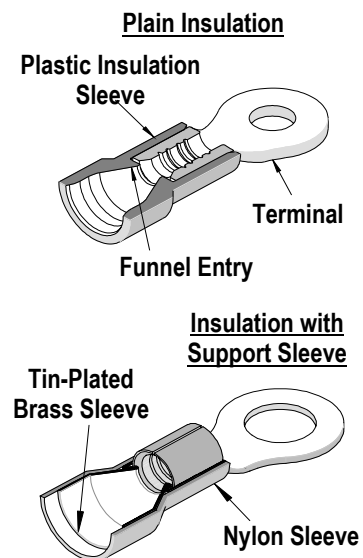
*UL - 486 C - Butt Splices, Parallel Splices, Closed End Connectors, and Wire Nuts

*UL - 310 - Quick Disconnects, Flag and Couplers

*Military Class 2- Military Approved Terminals only as listed

5.2 Barrel Serration/Dimples

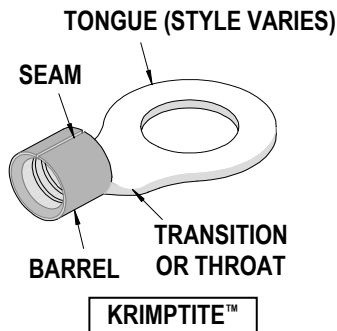
1. When quality solderless terminals are stamped, the inside of the barrel is scored with serrations or dimples.
2. When the crimp is made and the metal terminal barrel is drastically deformed, the tin plating on the inside of the barrel is fractured at the serrations, thus causing bare copper-to-copper contact between the wire and the terminal barrel. This greatly enhances electrical conductivity.
3. If properly designed, the serrations, or dimples, have angled grooves that, during the crimping operation, will bite into the wire, which will greatly increase the mechanical integrity of the crimp.
4. A quality solderless terminal has features built into the barrel that insures a quality crimp.
5. The non-insulated terminal will have a chamfer at the wire insertion end so the individual strands will not bump against the end of the metal.
6. On an insulated terminal the insulation should have a funnel entry. This acts as a guide for the wires to enter the barrel smoothly.
7. There are two styles of insulated barrels. Both have a funnel feature.



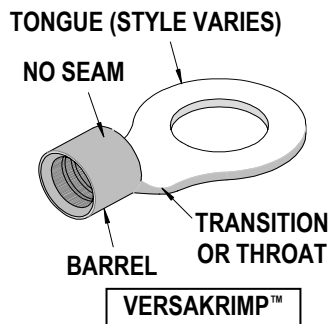
5.3 Barrel Styles

The barrel is the part of the terminal that is crimped around the wire. Molex offers different styles listed below.

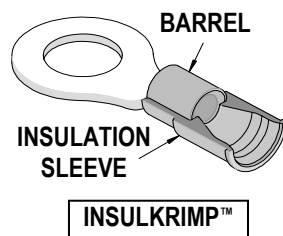
1. The **Krimptite™** is the basic Molex barrel style. It is non-insulated and is a one-piece design. This terminal is the most economical and has the greatest variety of uses where special features are not required. It is available in 10 to 26 AWG (0.10 to 6.60mm²).



2. The **Versakrimp™** is the same as the Krimptite™, except the seam is brazed (welded) closed. This brazed-seam barrel terminal will not open under conditions of stress or wire pull. This allows for crimping from any direction without the barrel opening up, and provides greater tensile strength. This terminal is ideal for hard to crimp solid and stranded wires. It is available in wire range 4/0 to 22 AWG (0.10 to 117.00mm²).

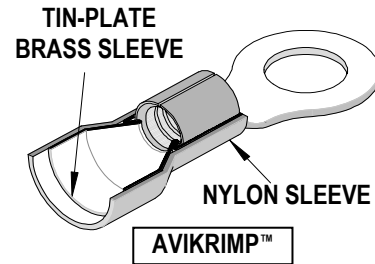


3. The **Insulkrimp™** has a rigid insulation sleeve made of PVC (polyvinyl chloride), which protection to the Krimptite barrel area in wire sizes of 10-22 AWG or the brazed seam of the Versakrimp barrel of 4/0 to 22 AWG. It is available in wire range 4/0 to 22 AWG (0.10 to 117.00mm²).

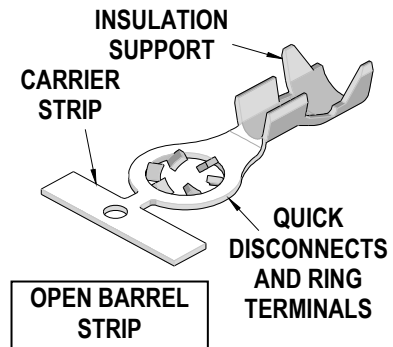


4. The **Avikrimp™** has a color-coded sleeve, which provides insulation as well as an insulation grip. The insulation is made of Nylon, and has a secondary tin-plated brass sleeve added. This brass support sleeve is crimped around the wire

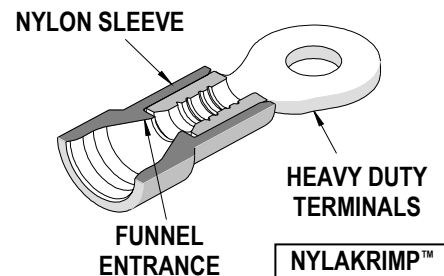
insulation providing a strain relief, so the wire does not vibrate, loosen, fray, or break. It is available in 10 to 26 AWG (0.10 to 6.60mm²).



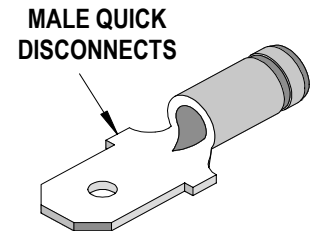
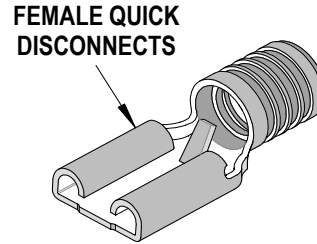
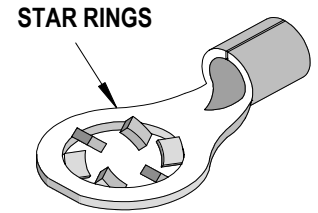
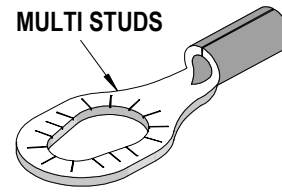
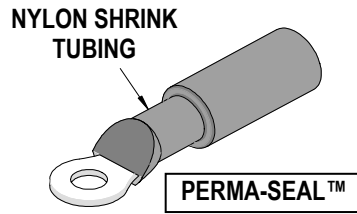
5. The **Open Barrel** product is used in manufacturing operations where quantity of work is needed. The open barrel allows the wire to be crimped faster and easier and is the barrel style preferred when using automated wire processing equipment.



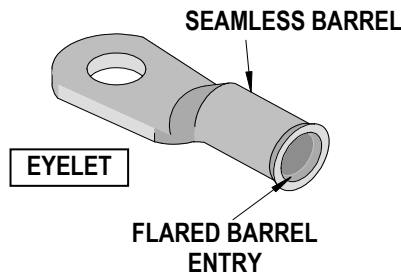
6. The **Nylakrimp™** is specifically designed for large wire applications. The color-coded barrel is affix with a permanent rigid color-coded nylon insulated sleeve. It has a funnel entrance that eliminates wire strand fold back. It is available in wire range 4/0 to 8 AWG (8.50 to 117.00mm²).



7. The Perma-Seal™ is specifically designed for water resistant applications. The color-coded barrel has a permanent rigid color-coded nylon insulated sleeve. It has a funnel entrance that eliminates wire strand fold back. It is available in wire range 10 to 22 AWG (0.10 to 6.60 mm²).

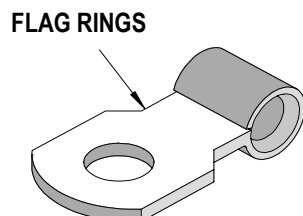
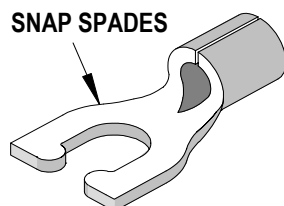
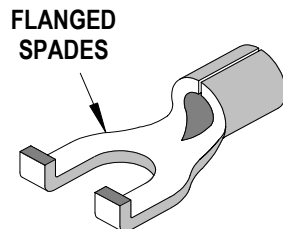
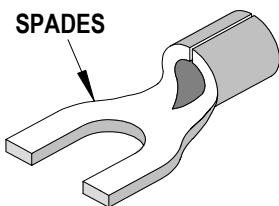
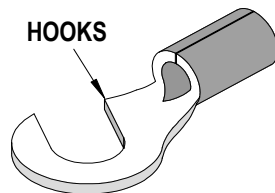
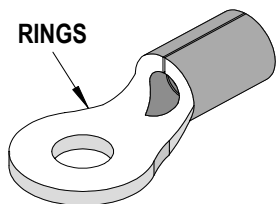


8. The Eyelet can be used in place of standard compression terminals because it is deep drawn from CDA-110 electrolytic pitch copper and then tin-plated for corrosion resistance. It has a seamless barrel with a flared barrel entry. It is available in wire range 8 to 500 MCM.



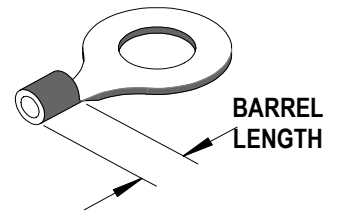
■ **Tongue Styles**

The “tongue” is the end of the terminal that attaches to other components (switch, stud, transformer, etc.). These tongue configurations vary. The following are some examples:



■ **Barrel Lengths**

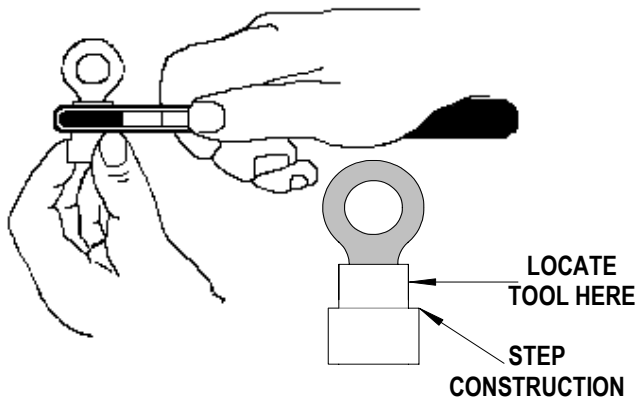
In wire sizes 26-16 AWG, the industry has two standard barrel lengths for the metal barrel. The lengths are 6.35 mm (.25”) and 4.36 mm (11/64”). The 4.36 mm barrel is the OEM (Original Equipment Manufacturer) standard barrel length. The 6.35 mm barrel is more commonly used in the maintenance and aftermarket segments of industry.



The purpose of the longer barrel is simply to give the user a bigger target area to crimp. These barrel lengths are not so important if you use a terminal with the molded step construction on the insulation, or if a precision ratchet tool with terminal locator is used. OEM tooling is usually designed for only short barrel terminals.

■ **Step Construction Insulation for Tool Location**

The “step” on the insulation of molded terminals is used to position (locate) the crimping tool. The tool should rest on the step and crimp made just above it. This insures that the entire width of the crimping tool is hitting on the barrel below. This step construction is very important when using a non-ratchet maintenance tool without a locator.



Insulation Barrel Colors

The colors on the insulation barrel (red, blue, and yellow) are used to indicate the wire range. The colors repeat themselves and are an industry standard color-coding. See the Chart below.

Color Code	Wire Range (AWG)
Yellow	24-26
Red	18-22
Blue	14-16
Yellow	10-12
Red	8
Blue	6
Yellow	4

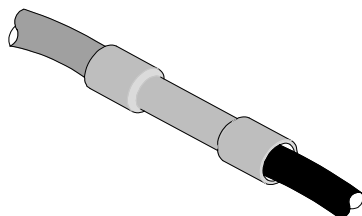
There are different kinds of barrels with different shades of the same color, which are used for different barrel styles. PVC and Nylon take the color differently. In the 14-16 AWG range (blue) for example, the PVC barrels will be dark blue. The nylon barrels will be a lighter, translucent blue. When using the lighter blue terminals, the secondary sleeve will be crimped in addition to the wire barrel crimp. The actual shade of color has nothing to do with quality of the insulation.

5.4 Splices

Molex offers standard and special splices for nearly every type of wiring need.

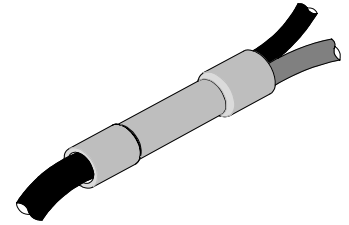
Butt Splices

On this connector, the stripped wires are inserted from each end and they "butt" in the center. Then a crimp at each end secures the connection.



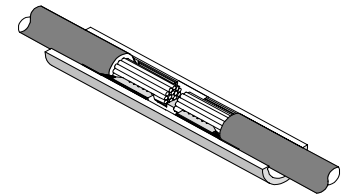
Step Down Butt Splices

The Step Down Butt Splice is the perfect solution when two wires need to be inserted in one end of a splice and a single wire in the other end.



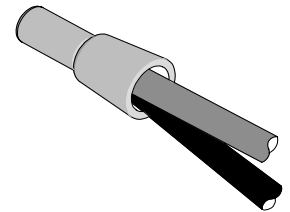
Avikrimp® Butt Splice

With the extra metal sleeve and nylon insulation, these splices should be used when heavy vibration is anticipated and a strong strain relief is needed.



Nylon Closed-End Connector

Used in a wide variety of situations to "pigtail" or tie together two or more wires.



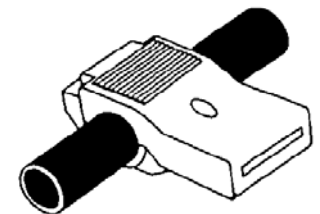
Funnel Entry Butt Splice

In the past, the crimping of machine terminated butt splices has been difficult and nearly impossible if attempted on a piece of robotic equipment. Now, with our new Funnel Entry Butt Splice, the end that will be crimped by the crimping press is funneled to allow quick and easy wire insertion.



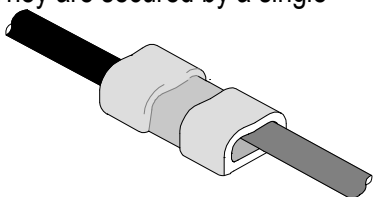
Perma-Seal Splices™

The tough sleeve of Perma-Seal splices resist abrasion and cutting. This protective helps to maintain the insulation and sealing properties even in hostile environments, not to mention unbeatable strain relief.



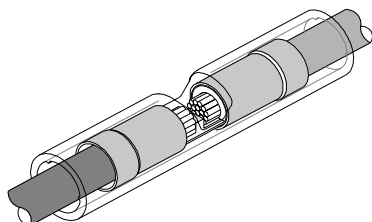
■ **Parallel Splice**

This connector has stripped wires that lie side-by-side in the splice. They are secured by a single crimp in the middle.



■ **Window Butt Splice**

This connector has military approval (Mil-T-7928/5) to withstand the harshest environments. The window guarantees proper wire insertion and crimp tool alignment. They are nylon insulated and have an insulation grip that provides superior strain relief.

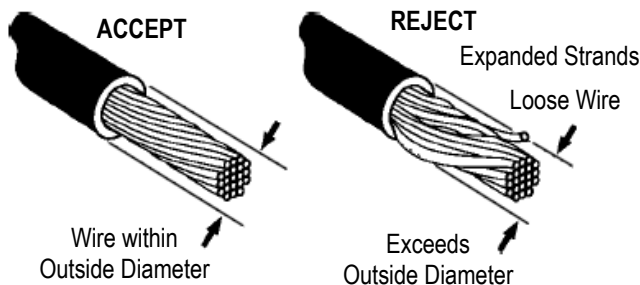


SECTION 6

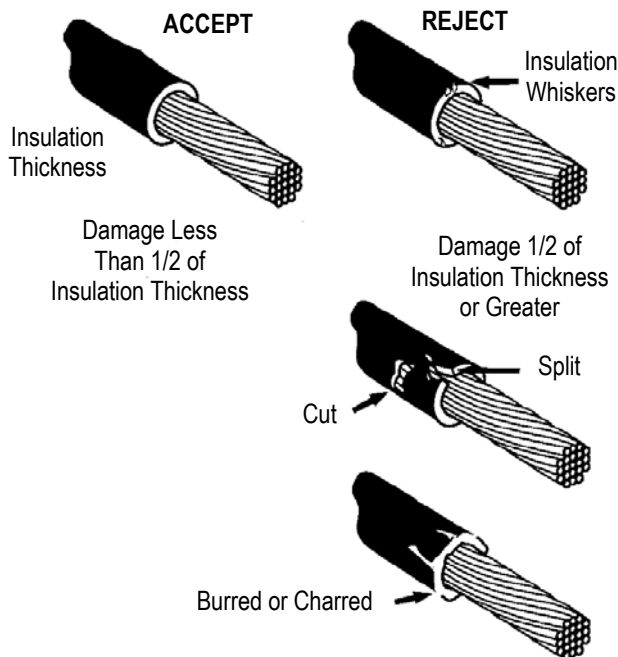
PROCEDURES

6.1 Preparing the Wire

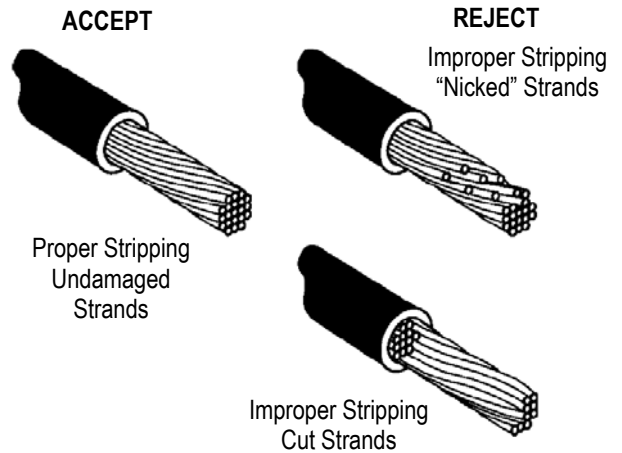
Check the stranded wire to see if any strands have loosened and expanded to be larger than the wire and the insulation together. If this has occurred, twist the wires to the size they were before they were stripped. Be sure that the stranded wire is within the outside diameter of the insulation after you have twisted them.



Check the insulation to ensure that there has been a nice clean cut. Wires with damaged insulation should not be used.

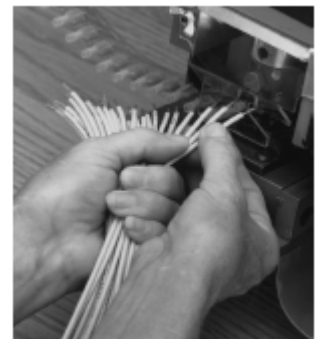


Check to see if the stripping tool or machine has cut or nicked any of the wires. If you see nicked wire you must cut and re-strip the wire before crimping to be sure that the amount of current that can be carried is not reduced.



6.2 Setup and Operation of a Press

1. Check that tooling is clean and not worn. If necessary, clean and replace worn tooling.
2. Disconnect power to the press and remove guarding devices.
3. Install the appropriate tooling into the press.
4. Load terminals into the tooling so that the first terminal is located over the anvil.
5. Manually cycle the press to help ensure a complete cycle can be made without interference. If it cannot, remove tooling and check press shut height. Go to procedure 3.
6. Check that the tooling is aligned. Check the impression on the bottom of the crimp that was made by the anvil tooling. Check that the extrusions and crimp form are centered. If not, align tooling and go to procedure 5.
7. Check that the terminal feed locates the next terminal over the center of the anvil tooling. If not, adjust terminal feed and the feed finger and go to procedure 5.
8. Re-install all safety devices that were removed during the set-up. **(Follow all safety requirements listed in individual press and/or tooling manuals.)**
9. Crimp sample terminals under power.
10. Evaluate cut-off tab length and conductor bell mouth. If adjustment is necessary, disconnect power to the press and remove guarding. Adjust



track position. Manually cycle the press and check the feed finger for feed location, go to procedure 7.

11. Evaluate conductor brush. If adjustment is necessary, disconnect power to the press and remove guarding. Adjust wire stop for bench applications or press position on automatic wire processing equipment. Go to procedure 8.
12. Evaluate insulation position. If necessary, adjust strip length, crimp new samples, and go to procedure 11.
13. Adjust insulation crimp height so the insulation crimp is not in contact with the wire insulation.
14. Crimp sample terminals.
15. Measure conductor crimp height (if applicable) and compare to specification. If necessary, disconnect power and remove guarding. Adjust conductor crimp height, install guards, connect power, and go to procedure 14.
16. Perform a pull force test.
17. Adjust insulation crimp.
18. Crimp sample terminals.
19. Evaluate insulation crimp. If necessary, disconnect power and remove guarding. Adjust insulation crimp height, install guards, connect power, and go to procedure 18.
20. Measure crimp height and compare to specification. If necessary, disconnect power and remove guarding. Adjust conductor crimp height, install guards, connect power, and go to procedure 18.
21. Document measurements.

6.3 Setup and Operation of a Hand Crimp Tool

1. Insure that the hand tool is designed to crimp the size wire and the proper terminal shown on the Hand Crimp Tool Specification sheet.

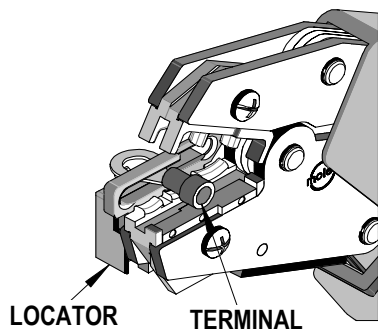
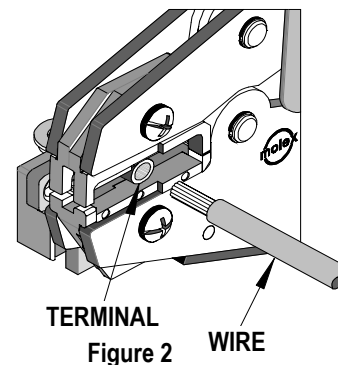


Figure 1

2. Strip the wire and make sure it is clear of any nicks or cuts. See Section "Preparing the Wire" above.

3. Place the terminal in the tool. Select the proper color-coded crimp nest.
4. If using a locator, lift the locator and insert the terminal in the proper nest with the barrel up and against the locator bar. Release the locator blade to hold the terminal in position. See Figure 1. Locator may be raised or lowered so terminal sits flat and straight in tool. The locator must be removed to run splices.
5. Insert the wire. See Figure 2.



6. Squeeze the handle. All production hand tools should have a built in full-cycle ratchet mechanism.
7. Inspect for proper crimp location. Check the Hand Crimp Tool Specification sheet that you are using for correct conductor crimp height.

6.4 Setup and Operation of a Air Powered Crimp Tool

1. Insure the Air Crimp Tool is designed to crimp the size wire and the proper terminal shown on the Air Crimp Tool Specification Sheet.
2. Strip the wire and make sure it is clear of any nicks or cuts. See Section "Preparing the Wire" above.
3. Place the wire into the terminal. Select the proper color-coded crimp nest.

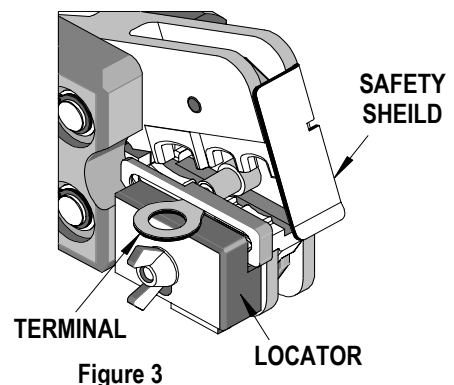


Figure 3

4. If using a locator, lift the locator and insert the terminal with the wire in the proper nest with the barrel up and against the locator bar. Release the locator blade to hold the terminal in position. See Figure 3. Locator may be raised or lowered so terminal sits flat and straight in tool. The locator must be removed to run splices.
5. Push on the wire to assure it is still fully seated in the terminal. Cycle the tool. See Figure 4.

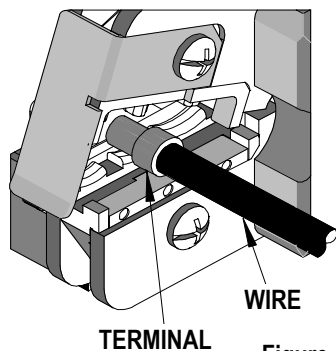


Figure 4

6. Inspect for proper crimp location. Check the Air Powered Crimp Hand Tool Specification Sheet that you are using for correct conductor crimp height

Caution:
 Never operate this tool without the supplied safety shield in place. Never place fingers in the tool nests.

Note: Whenever crimping without the locator, make sure the seam of the barrel is oriented up or down in the tool as this will provide higher pull force values.

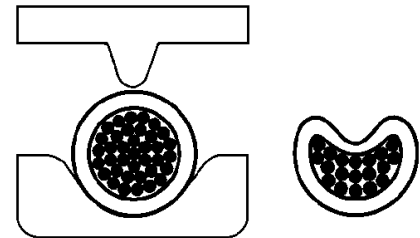
6.5 Crimping Dies

The Molex product line includes seven types of dies for different terminals:

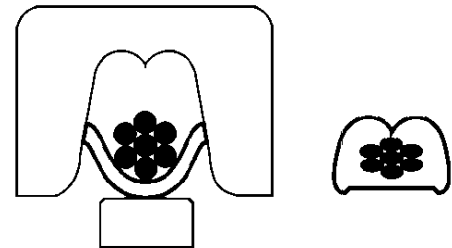
- Two piece INDENTOR CRIMP, VersaKrimp™
- Two piece CONFINED CRIMP, Krimptite™ and VersaKrimp™
- Two piece CONFINED CRIMP, InsulKrimp™ and AviKrimp™
- Two piece F TYPE CRIMP, Krimptite™ and VersaKrimp™
- Four piece F TYPE CRIMP, VibraKrimp™

Four piece CONFINED CRIMP, InsulKrimp™ and AviKrimp™.
 Bottom INDENTOR CRIMP, 8 and 6 AWG VersaKrimp™.

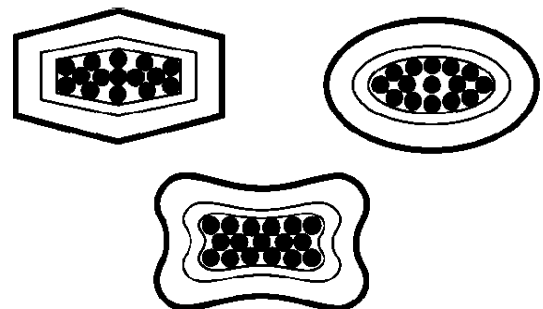
- The Indentor crimp consists of a holding nest and indentor ram to deform the barrel. The advantage of this configuration is that while it covers a broad range of wire sizes, it is still easy to design and inexpensive to manufacture.



- The F crimp is used to close the barrel and confine the individual strands. The overall quality is excellent.



- The Confined crimp gives the best overall crimp. It is in the shape of a hexagon, an enclosed "C", or a confined quad. The advantages of all three crimps are uniformity and compression of individual strands and uniform outer appearance.



Molex provides a complete line of fully automatic wire processing machines, semi-automatic and manual wire crimping tools. Each system is tailored to our customer's individual needs by using support equipment, and can be adapted to wire processing equipment offered by manufacturers

such as ARTOS, KOMAX, and others. This Manual shows the basics of Manual and Semi-Automatic equipment.

SECTION 7

QUALITY CRIMPS

Quality is something that must be measured by some set of criteria. Four major agencies give test criteria for quality of solderless terminals. They are:

- U.L. (Underwriters Laboratories)
- CSA (Canadian Standard Association)
- NEMA (National Electronic Manufacturers Association)
- Federal Government Spec - Mil-T-7928

In all of the above standards specific reference is made to the following areas:

- Copper or brass quality specifications
- Tin-plating specs type and thickness
- Smoothness of edges and lack of burrs
- Firmness of fit between metal and insulation

Then there is a whole series of tests to be performed on the crimp area after the crimp is made:

- Tensile test
- Dielectric withstand
- Salt spray
- Vibration
- Heat rise

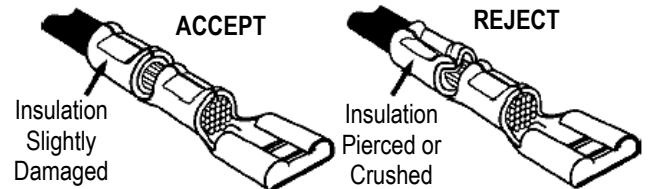
The most widely used field test for testing the quality of the crimp is the pull test, or tensile test.

The two most widely used measurements are the U.L. and Military Tensile values. See Section 8. Note that the Military pull force is higher than the U.L.

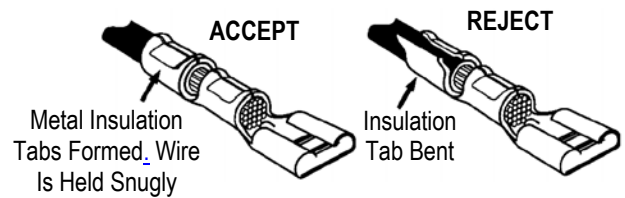
7.1 Visual Inspection of **OPEN BARREL** Crimps

▪ Insulation Not Damaged

1. Crimp the insulation just enough (may have a slight indentation to hold the wire in place). If the insulation has been pierced or crushed, the wires inside may have been damaged also.
2. Be sure that the conductor insulation has not been pierced or crushed by the crimp.



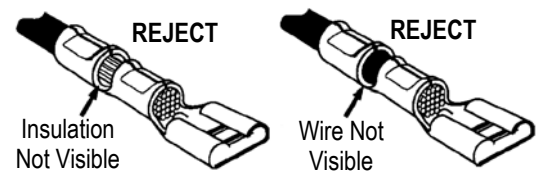
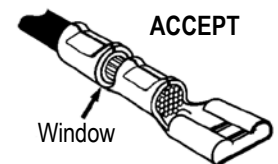
▪ Insulation Support Crimp



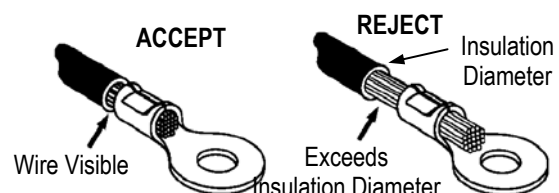
1. Be sure that the insulation barrel tabs are not bent.
2. Form the tabs properly.
3. If one of the tabs is bent, the insulation crimp will not be strong enough to provide the needed stress relief.

▪ Wire Visible

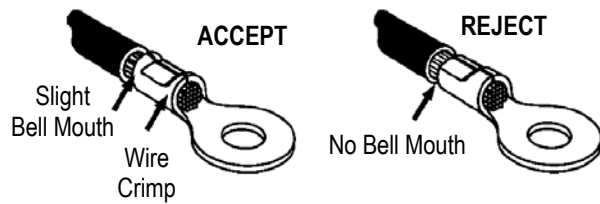
1. Be sure that both the wire and the insulation are visible in the window.
2. If only the insulation is visible, you may have crimp insulation in the conductor barrel.
3. If only the bare wire is visible, you cannot assume that the insulation has been properly crimped.



4. If there is no insulation support crimp, be sure that the length of the wire visible behind the conductor crimp is not greater than the diameter of the insulation. If the length of the wire visible exceeds the diameter of the insulation, the terminal could cause a short circuit.

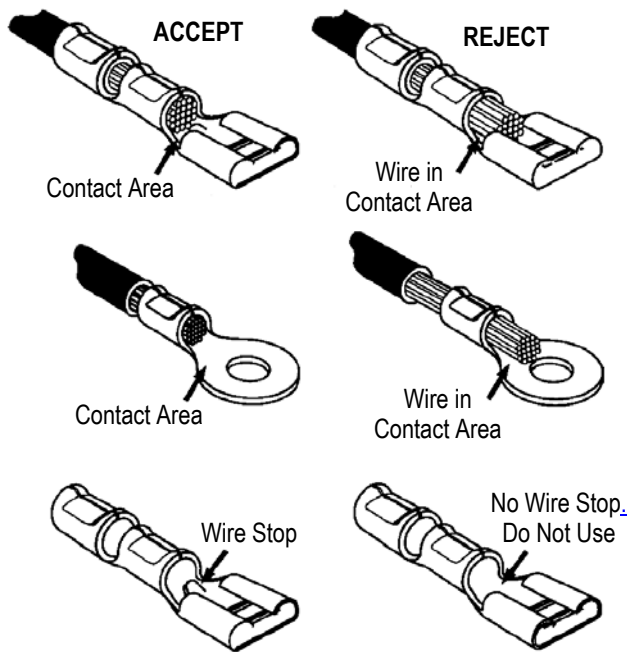


■ **Good Bell Mouth Present**



1. Be sure that a good bell mouth is present in the wire barrel.
2. If no bell is present, the sharp edge of the wire barrel may cut or nick the wires.

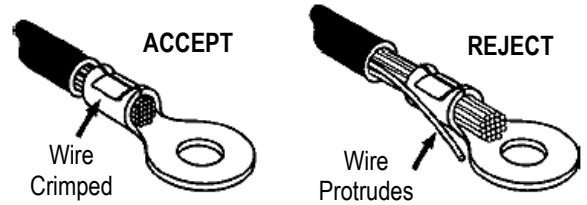
■ **No Wire Strands in the Contact Area**



1. Be sure that no wire strands extend into the contact area of the lug or terminal.
2. If the wire strands are in the contact area, they will interfere when the terminal is connected.

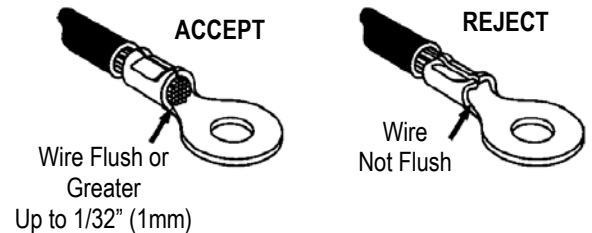
■ **No Strands Sticking Out (Strand Fold Back)**

1. Be sure that all of the wire strands are twisted together, and are equal to the size they were before being stripped.
2. If the strands are not together, or if one is left sticking out, your wire mass is reduced and can cause both electrical and mechanical problems.

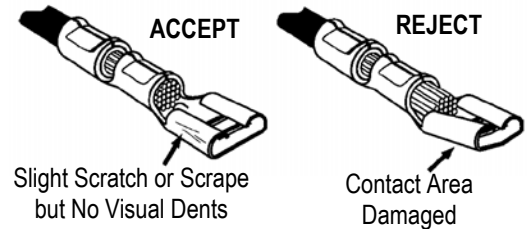


■ **Wire Extension**

1. Be sure that the wires extend not more than 1/32" (1mm) past the end of the barrel. If the wires are not flush or greater, you will not be able to see if the crimp is complete and correct.



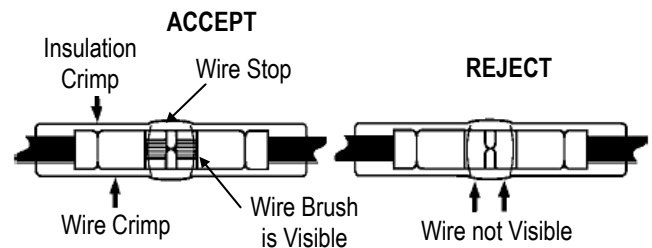
■ **No Damage to the Contact Area**



1. Be sure that the contact area is not dented or crushed.
2. If it is dented or crushed (slight scratch or scrape is permissible), the connection between the terminal and another component cannot be made properly.

7.2 Visual Inspection of **CLOSED BARREL** Crimp

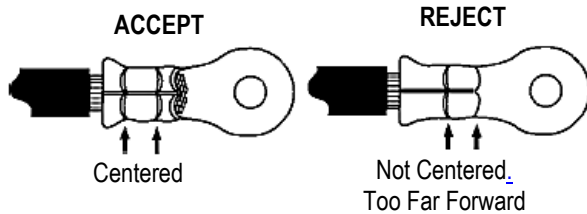
■ **Wire Visible**



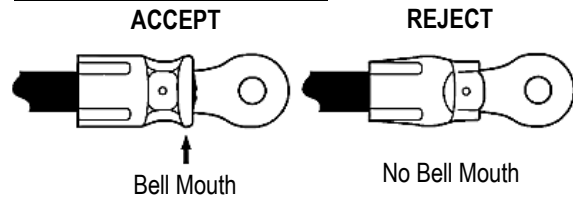
1. Be sure that the wire is visible in the inspection window so that there is evidence of a good crimp. See Butt Connector above.

■ **Crimp to be Centered**

1. On all crimped terminals, the conductor crimp should be centered on the conductor barrel. This insures even pressure on the entire length of the barrel.

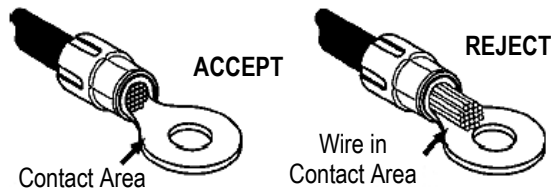


■ **Good Bell Mouth Present**



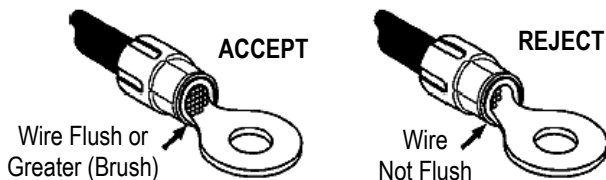
1. Be sure that a good bell mouth is present on the wire barrel.

■ **No Wire Strands in the Contact Area**



1. Be sure that wire strands do not exceed into the tongue area of the lug or terminal.
2. If the wire strands are in the contact area, they will interfere when the terminal is connected.

■ **Wire Flush or Greater**



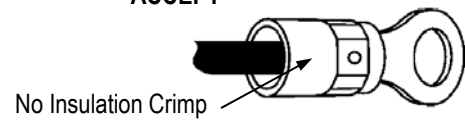
1. Be sure that the wires are either flush with the end of the conductor barrel or extend past the barrel.
2. This "brush" extension should be approximately 1/32" (1mm).
3. If the wires are not flush or greater, you will not be able to see if the crimp is complete.

■ **Wire Size (AWG) Requirements**

1. To achieve a quality crimp be sure to follow the proper insulation crimp for different wire sizes.

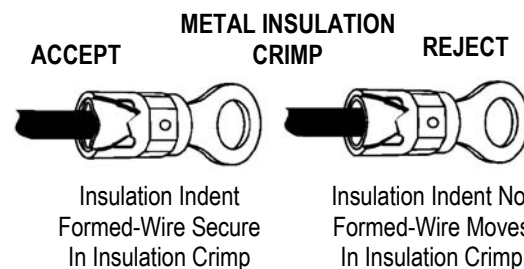
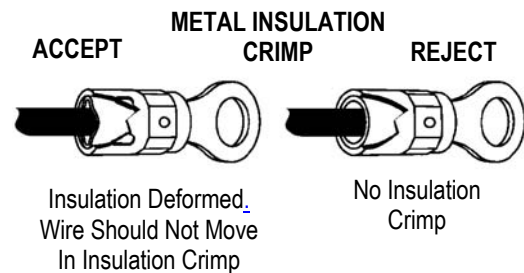
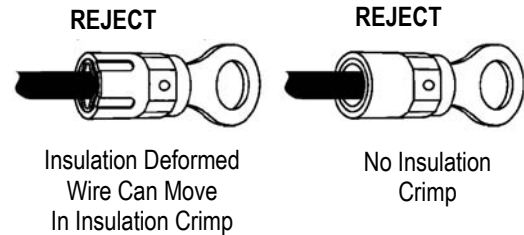
Wire sizes of 8 AWG and larger do not require an insulation crimp.

ACCEPT

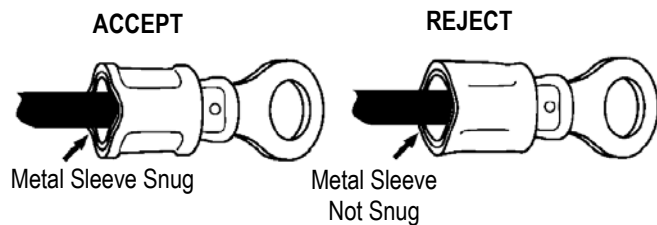


Wire sizes 18 thru 10 AWG require an insulation crimp to securely hold the wire insulation crimp.

PLASTIC INSULATION CRIMP



■ **Insulation Support Crimp**



1. On closed barrel terminals that have a secondary metal sleeve (AviKrimp™), the metal sleeve should be formed snugly around the wire.

SECTION 8

IMPORTANCE OF PROPER CRIMPING

Once the correct terminal is selected, proper attachment to the wire is critical. One indication of the importance of proper crimping is evidenced in a study for the Space Shuttle Program that traced 28% of all defects to improperly assembled wiring and connectors. Mechanical as well as electrical connections are important - The result of a properly crimped joint is a reliable mechanical and electrical connection.

The mechanical connection is the crimping of the terminal to the conductor. The desired result is sufficient force on the outside of the barrel to tightly form it around the conductor. It must be secure enough not to vibrate loose or to be pulled off through normal use.

The electrical characteristics are just as important. The major concern is the amount of electrical resistance caused by the mechanical joint. The electrical resistance will determine the crimped joint's ability to conduct current

8.1 Conditions

To achieve a positive relationship between the mechanical and electrical connection in the crimped joint, the following conditions are required:

1. The terminal must be of sufficient cross section size and conductive material that it is as good an electrical conductor as the wire.
2. The surfaces of the wire and terminal that will be pressed into contact in the crimp must be clean and free of heavy, non-conductive films such as oxides, sulfides, and similar substances.

Some reasons for failure of crimped joints to meet minimum tensile requirements include nicked wires, nicked or ruptured strands, strand turn back at crimp joint, and ruptured wires outside of the crimped terminal. To avoid these problems, use the correct size wire for the barrel, prepare your wire carefully, and use the proper crimping tool.

8.2 Testing

Mechanical

The tensile test or pull test is a means of evaluating the mechanical properties of the crimped connection. The chart on this page shows the UL and Military Specifications (MIL-T-7928) for various wire sizes. The tensile strength is shown in lbf (pound-force), it indicates the minimum acceptable force to break or separate a terminal from the conductor.

When the crimp is made, there must be enough pressure applied so that the oxides that may build up on the stripped conductor and the tin plating on the inside of the terminal barrel are broken down and there is good metal-to-metal contact. If this situation does not occur, the resulting crimp will have unacceptably high resistance.

Tensile Strength in Pound-force				
Wire Size (AWG or MCM)	*UL-486A	*UL-486-C	*UL-310	*Military Class 2
26	3	N/A	N/A	7
24	5	N/A	N/A	10
22	8	8	8	15
20	13	10	13	19
18	20	10	20	38
16	30	15	30	50
14	50	25	50	70
12	70	35	70	110
10	80	40	80	150
8	90	45	N/A	225
6	100	50	N/A	300
4	140	N/A	N/A	400
2	180	N/A	N/A	550
1	200	N/A	N/A	650
1/0	250	N/A	N/A	700
2/0	300	N/A	N/A	750
3/0	350	N/A	N/A	825
4/0	450	N/A	N/A	875
250 MCM	500	N/A	N/A	1000
300 MCM	550	N/A	N/A	1120
350 MCM	600	N/A	N/A	1125

*UL - 486 A - Terminals (Copper conductors only)

*UL - 486 C - Butt Splices, Parallel Splices, Closed End Connectors, and Wire Nuts

*UL - 310 - Quick Disconnects, Flag and Couplers

*Military Class 2- Military Approved Terminals only as listed

Dielectric Testing

(The term “dielectric” refers to an insulator.)

Some terminals are covered with insulation so that electrical contact can be made only where it is desirable. The crimp is made through (on) this insulation, which is compressed and extruded due to the pressure of the crimping dies. Obviously, not all insulation materials can withstand this treatment and even with the strongest materials, the crimp must be correctly designed so as not to rupture the insulation.

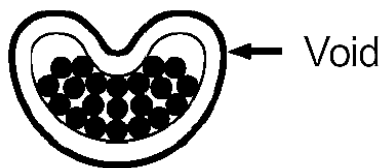
Dielectric tests are made on insulated terminals after crimping to determine that the crimp process is not rupturing the insulation or thinning it out so that it will not withstand impressed voltages. The test is made by impressing a voltage between the wire to which the terminal is crimped and conductive materials contacting the terminal insulation.

The voltage is gradually increased until the requirements are reached or until a breakdown occurs which means the insulation breaks. Depending on the use and the specifying agency, dielectric withstanding requirements normally range from 1500 to 8000 volts, resulting in a 300 to 600 volt rating of the terminal.

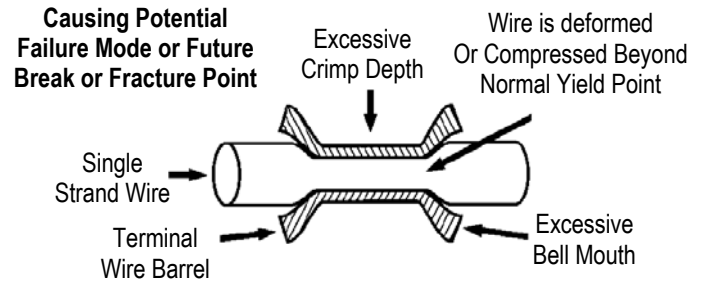
8.3 Final Tensile Value

The type of die affects the final tensile value in several ways. See Crimping Dies, Section 6.5.

If the die (as in the indenter type) does not indent far enough, a void may be created in the compression joint permitting the individual strands to shift, thus loosening the connection. Further, the air space (void) acts as an electrical insulator.



If the die presses too tightly the individual strands can be squeezed and elongated. This can cause a weak point in the conductor, cause the wire to break at a lower than allowable tensile strength, and/or create a heat rise across the joint because of lower cross-section and increased resistance.



Another way to cause tensile failure is not compressing the barrel enough to hold the conductor securely. Molex crimp tools are designed to eliminate these problems.

8.4 Electrical Resistance

The electrical resistance across the crimp is compared to the resistance of an equal length of wire, and expressed as relative resistance for a particular wire size.

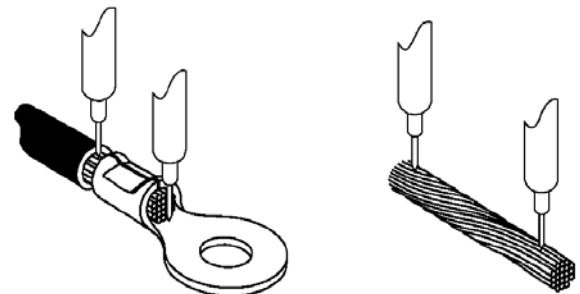
Relative resistance of the crimp to the wire is given by the formula below:

$$\text{Relative resistance} = \frac{R_C}{R_W}$$

Where:

R_C = Resistance over crimp

R_W = Resistance of wire



Relative resistance values of less than 1.0 denote a crimped joint with less resistance than the wire; values more than 1.0 indicate greater resistance than the wire. Usually it is easier to measure the voltage drop across the crimped joint. Many specifications state the requirements in terms of voltage drop at a specified current. Voltage drop is the more commonly used term in the industry. If the resistance value is desired, it may be calculated from Ohm's Law:

$$R = \frac{E}{I}$$

Where:

- R is the resistance (in milliohms)
- E is the voltage drop (in millivolts)
- I is the current flowing (in amperes)

Crimp voltage drop and resistance values are quite small and are expressed in terms of millivolts (.001 volts) and milliohms (.001 ohms).

A crimp joint of poor quality could be caused by several factors. It is indicated by increased resistance, which cause increase in voltage drop value.

For example, the presence of air pockets or voids in the crimped joint will cause a higher resistance (smaller area of contact between terminal and wire). Increased resistance results in a higher voltage drop and a temperature rise, which in turn increases the corrosion rate and further increases the resistance.

A crimped joint that has been over-crimped and the conductor (wire) elongated out of shape could cut the circular area of the conductor and cause a greater resistance at this weakened point.

8.5 Crimp Joints

A finely stranded wire (large number of small diameter strands) usually improves crimped joint performance. A wire composed of a few strands of larger size will tend to act as a solid wire in the crimp. Some stranded wire crimp configurations are not satisfactory for solid wire. More deformation must be imposed in order to form wire and barrel into a solid mass. On the other hand, finer strands will more readily fill the inside

corners of the crimp shape and more evenly distribute the forces of the crimp.

Brazed barrel terminals usually give higher tensile test than the non-brazed (for specific values, tensile tests must be performed on each terminal).

Annealing

When the metal part of a solderless terminal is stamped on a stamping press; the strip of metal material is repeatedly hit in the stamping process.

These terminals are made on progressive dies.



This repeated hitting causes the metal (usually copper) to become work hardened. Copper gives its best mechanical and electrical characteristics when it is in its original (not work hardened) state.

In order to return the work hardened copper to its normal soft and malleable state, it must be annealed. Annealing is accomplished by heating the metal (copper) terminal in a furnace, and then cooling it slowly. This process restores the copper to its original state.

How does annealing (or lack of) affect the crimp barrel and quality of a solderless terminal?

When a work-hardened terminal is crimped, it does not form around the wire in a uniform fashion, thus giving sharp angles, which allows for voids. The annealed barrel can be easily formed, giving uniform pressure on the wire and thus a superior crimp.

SECTION 9

MISCELLANEOUS

AWG-CMA Table	
Terminal Size /AWG	CMA Range
26-22	202-810
24-20	320-1,020
22-18	509-2,600
22-16	509-3,260
16-14	2,050-5,180
14-12	3,260-8,213
12-10	5,180-13,100
8	13,100-20,800
6	20,800-33,100
4	33,100-52,600
2	52,600-83,700
1/0	83,700-119,500
2/0	119,500-150,500
3/0	150,500-190,000
4/0	190,000-231,000

Technical Wire Information

CMA — Circular Mil Area. Circular Mil is a unit of area equal to that of a circle whose diameter is one Mil.

MIL — One mil equals .001 inches.

.001" = 1 mil

.030" = 30 mils

.125" = 125 mils

Changing Inches to Mils

1. Multiply inches by 1000 or,
2. Move decimal point 3 places to right or,
3. Change terminology, i.e. 0.032 in. = 32 thousandths or 32 mils.

Computation of CMA

Round Solid Conductor:

Change diameter from inches to mils, and then multiply the diameter "D" in mils by itself.

$$CMA = D \text{ mils} \times D \text{ mils}$$

Stranded Conductor:

Find CMA of a single strand and multiply the result by the total number of strands.

$$CMA = (D \times D) \times \text{Number of Strands of one Strand}$$

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