

QUALITY CRIMPING HANDBOOK



PRODUCED BY THE MOLEX
APPLICATION TOOLING GROUP

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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. But 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 end 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 so 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 x 19 strand wire than an 18 AWG x 16 strand. The insulation diameter of an 18 AWG wire can range from .070" (1,78 mm) to over .180" (4,57 mm). Wire strands can be copper, tinned, overcoated, or topcoated. 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.



1.0 PURPOSE

This handbook provides general guidelines and procedures for understanding and achieving acceptable crimp terminations. A Glossary in Chapter 3 lists common terms and definitions. Chapter 4 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, bellmouth, 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 bellmouth 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. Chapter 5 has a flowchart for a process setup while Chapter 7 is a trouble shooting guide for common problems. Using Statistical Process Control (SPC) during the crimping process can help minimize the Parts per Million (PPM) reject levels. Chapter 6 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.

2.0 SCOPE



This handbook is intended for Molex customers who are crimping Molex open barrel crimp terminals and are using Molex tooling, primarily in semi-automatic 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.

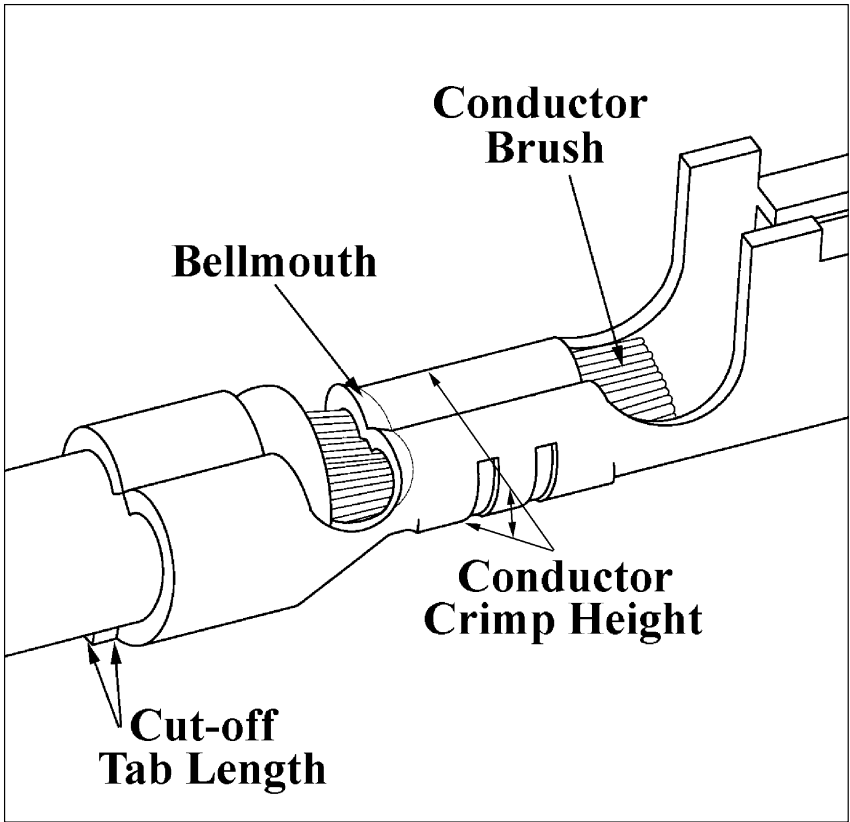
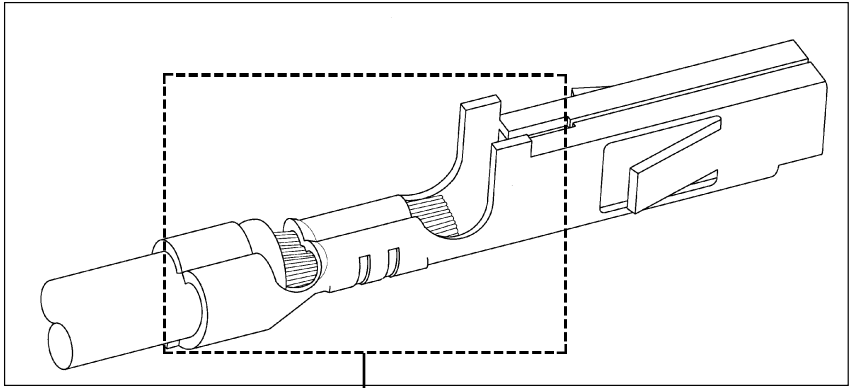


Figure 1 - Terminal Anatomy

3.0 DEFINITIONS

(Anatomy of a Crimp Termination)



BELLMOUTH (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 bellmouth needs to be approximately 1 to 2x the thickness of the terminal material *.

* Consult individual terminal specifications

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 general 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 most radial surface. Do not include the extrusion points in this measurement (See Figure 2, pg. 10). 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 platings. Although it is possible to optimize a crimp height to individual wire strandings and terminal platings, one crimp height specification is normally created.

CUT-OFF TAB LENGTH

This is the material that protrudes outside the insulation crimp after the terminal is separated from the carrier strip. As a general rule, the cut-off tab is approximately 1.0 to 1.5x terminal material thickness *. 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 setup to provide a cut-off tab that is flush to one material thickness.

* Consult individual terminal specifications requirements.

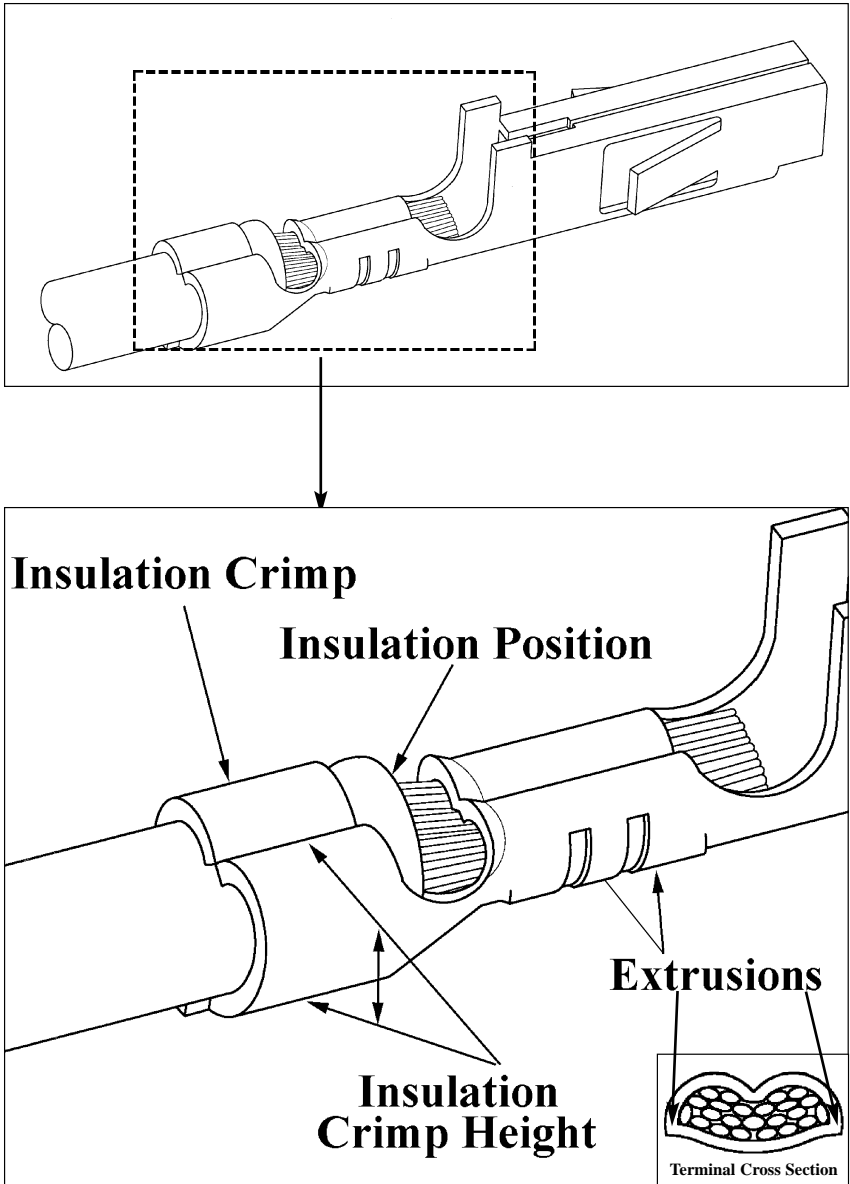


Figure 2 - Terminal Anatomy

EXTRUSIONS (FLASH)

These are the small flares that 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 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 both wire support for insertion into the housing and 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 or not 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 terminals range, an insulation diameter 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 should firmly grip at least 88% of the wire.
- A smaller insulation 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 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 gets 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.

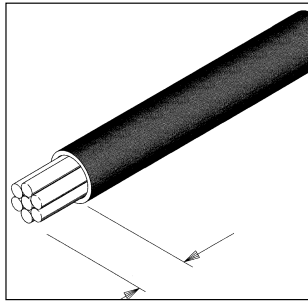


Figure 3 - Strip Length

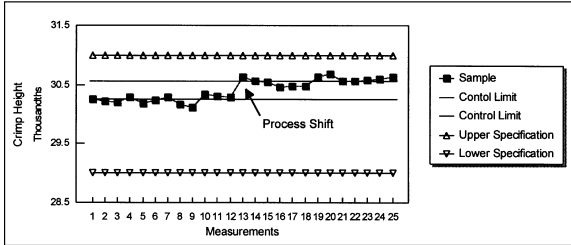


Figure 4 - Process

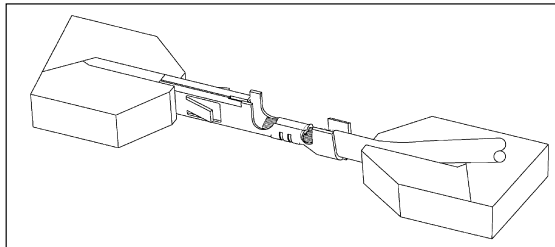


Figure 5 - Pull Force Tester

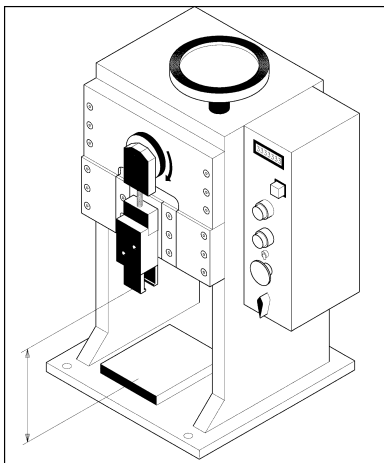


Figure 6 - Press Shut Height

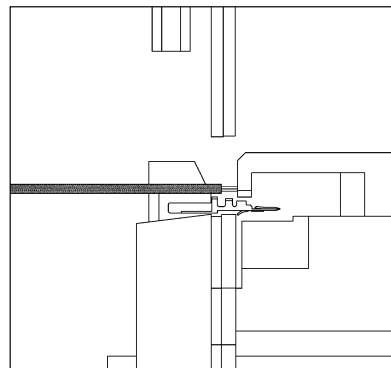


Figure 7 - In Press Terminal Position

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.

PROCESS

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

Pull Force Testing is a quick, destructive way to evaluate the mechanical properties of a crimp termination. When making a crimp, enough pressure must be applied to breakdown the 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.

Pull Force testing is also a good indicator of problems in the process. Cut or nicked strands in the stripping operation, lack of bellmouth 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 pull force levels.

SHUT HEIGHT

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

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 bellmouth, cut-off tab length, and terminal extrusions.

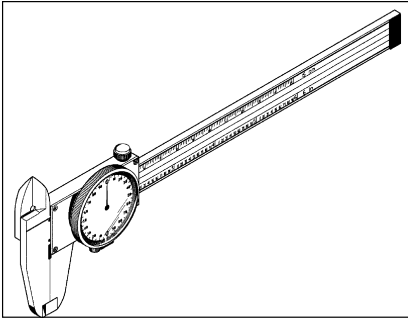


Figure 8 - Caliper

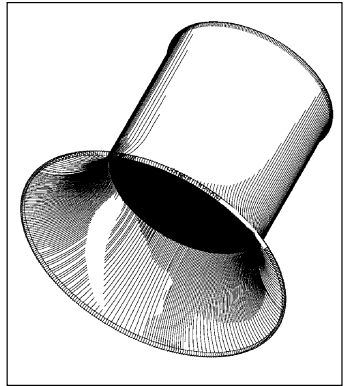


Figure 9 - Eye Loop

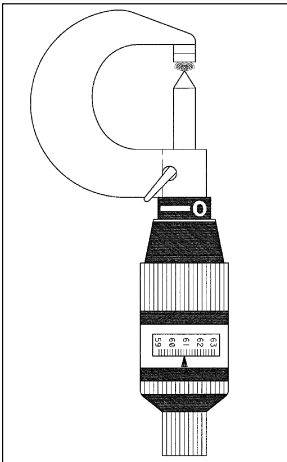


Figure 10 - Crimp Micrometer

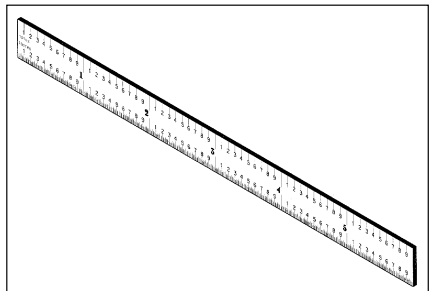


Figure 11 - Pocket Ruler

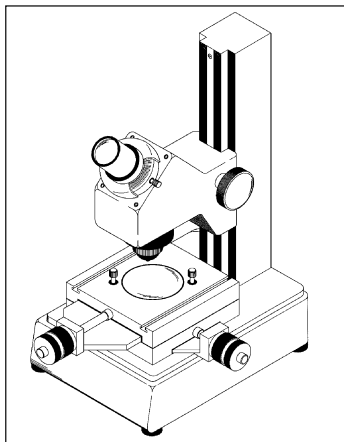


Figure 12 - Toolmaker's Microscope

4.0 ASSOCIATED MATERIALS



CALIPER

A gage, consisting of two opposing blades, for measuring linear dimensional attributes.

EYE LOOP

A magnification tool, normally 10x 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 it is not influenced by the conductor bellmouth. It has a thin blade that supports the top of the crimp while a pointed section determines the bottom most radial surface.

RULER (POCKET SCALE)

This is used to estimate the five piece measurement of bellmouth, cut-off tab, conductor brush, wire position, and strip length. The recommended maximum resolution is .5 mm (.020 in).

PULL TESTER (Reference fig. 5, pg.12)

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 bellmouth, cut-off tab, conductor brush, wire position, and strip length.



5.0 PROCEDURES

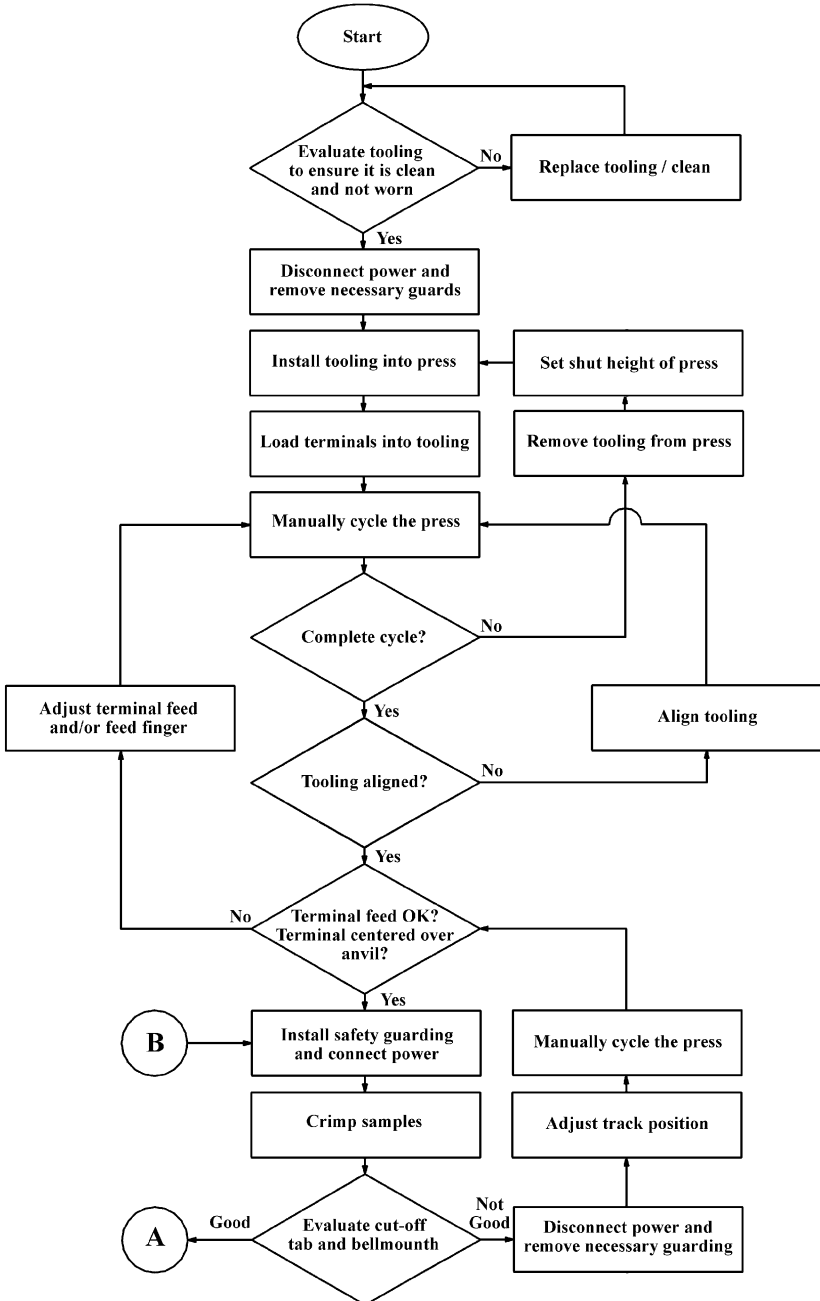
5.1 TOOL SETUP (Reference Procedures Flow Chart)

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 bellmouth. 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.

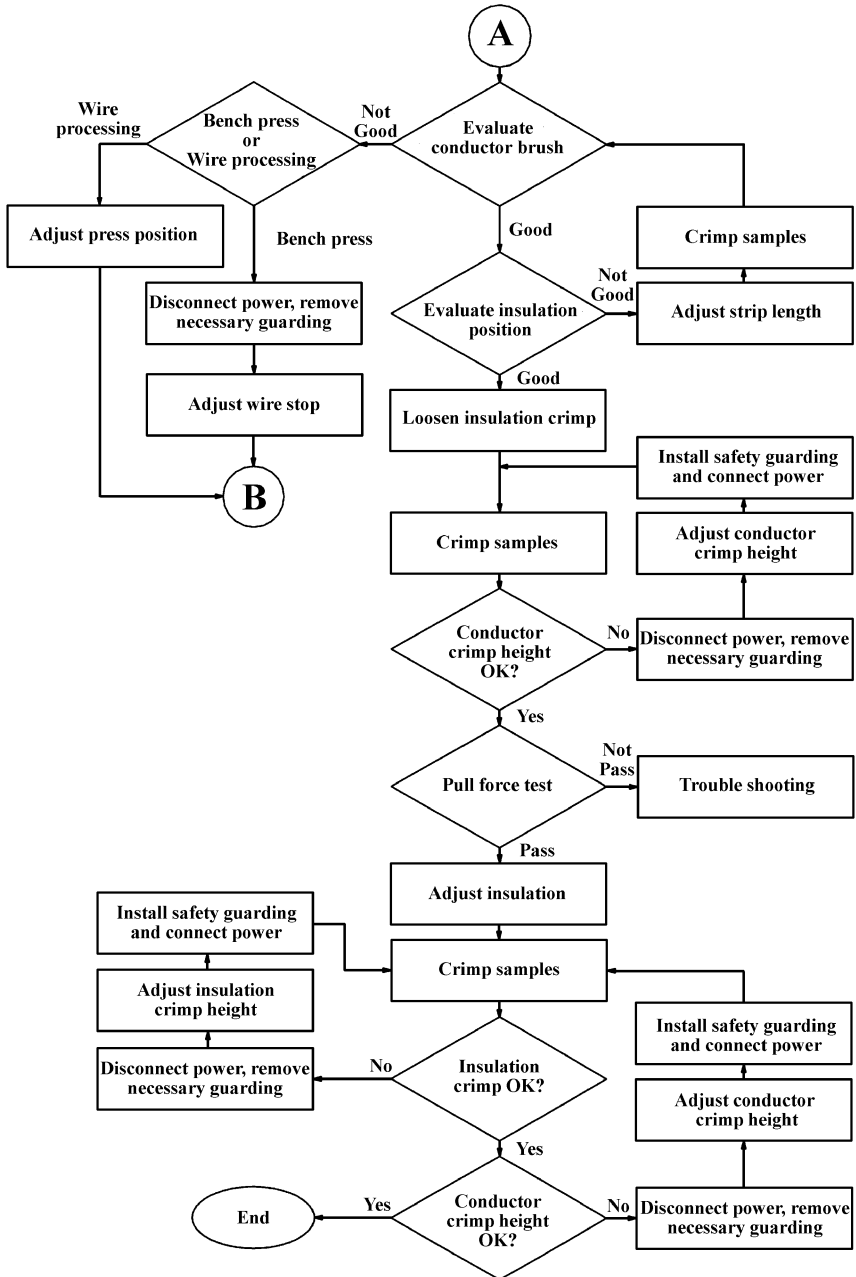


13. Loosen insulation crimp height.
14. Crimp sample terminals.
15. Measure conductor crimp height and compare to specification. If necessary, disconnect power and remove guarding. Adjust conductor crimp height, install guards, connect power, and go to procedure 14.
16. Perform a pull force test. If it fails, refer to trouble shooting.
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.



FLOW CHART

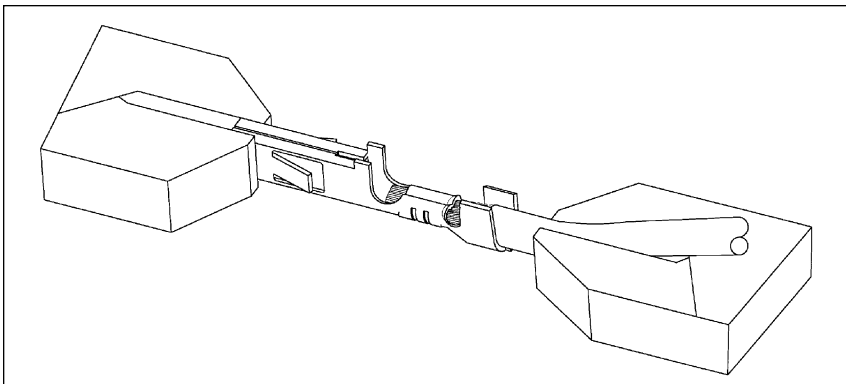




6.0 MEASUREMENT

6.1 PULL FORCE TESTING

1. Cut wire length approximately 6 inches (152 mm) long.
2. Strip one end to 1/2 inch (13 mm) 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 bellmouth, wire brush, and cut strands.
5. Set pull tester to 2" per minute (50 mm/min). 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 2" 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 5 pull force measurements should be done to confirm each set-up. A minimum of 25 readings should be taken for capability.
10. Compare lowest reading to minimum pull force specification.



Note: High variability and lower CpK's are common for double wire applications. The variability is due to more variation in conductor brush, conductor bellmouth and fewer strands of one wire being in contact with the serrations on the terminal barrel. A double crimp application 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

Test Values for Pullout Test UL486A

Size of Conductor		Pullout Force*	
AWG	(mm ²)	LBS.	(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

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

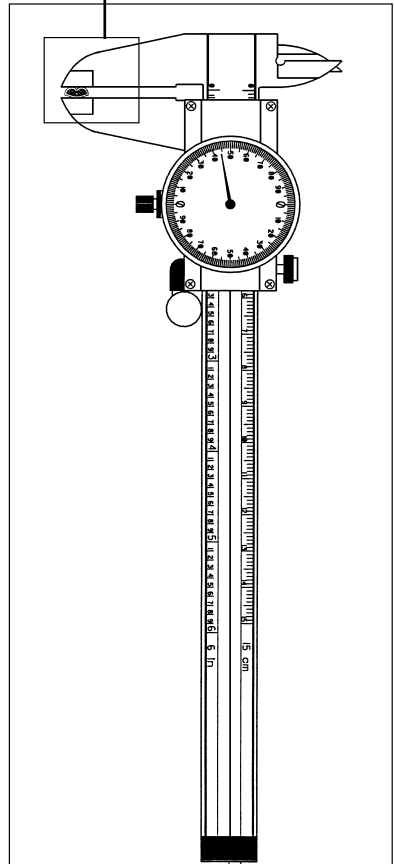
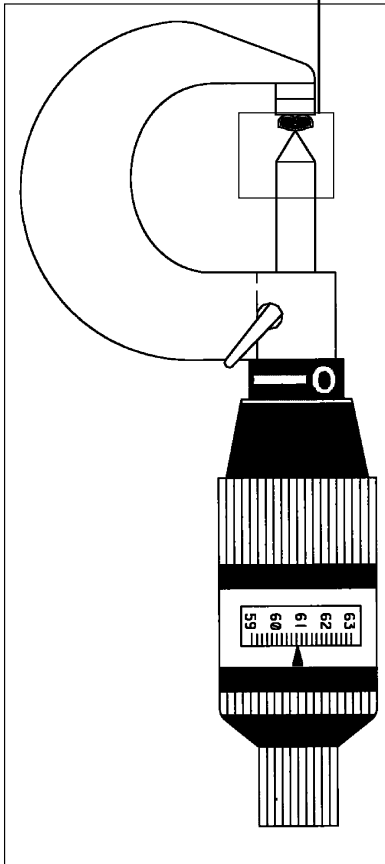
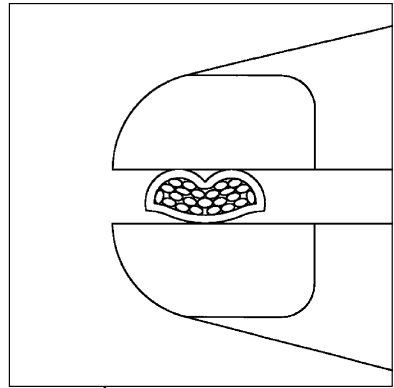
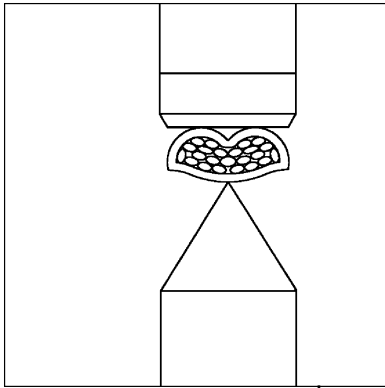


Figure 14 - Crimp Micrometer

Figure 15 - Caliper

6.2 CRIMP HEIGHT TESTING

1. Complete tool set-up procedure.
2. Crimp a minimum of 5 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 bellmouth.
4. Rotate the micrometer dial until the point contacts the bottom most radial surface. If using a caliper, be certain not to measure the extrusion points of the crimp.
5. Record crimp height readings. A minimum of 5 crimp height readings are necessary to confirm each set-up. A minimum of 25 readings are necessary to determine 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.



7.0 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 can save a harness manufacturer thousands of dollars in potential rework or re-manufacturing.

Variability is the slight changes that occur 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 are 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 at 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 result from a damaged tool may be undetected until thousands of crimps are made.

7.1 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.

CpK	+/- 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 each specification. A capability index is defined by the formula below. Cp may range in value from 0 to infinity, with a larger value indicating a more capable process. A value >1.33 is considered acceptable for most applications.

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

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

$$\frac{(\text{USL} - \text{MEAN})}{3 * \text{Standard Deviation}} \qquad \frac{(\text{MEAN} - \text{LSL})}{3 * \text{Standard Deviation}}$$

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; a crimping hand tool produces 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 gage 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 gages. Molex recommends a gage 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 CpK's low.

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



7.2 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.

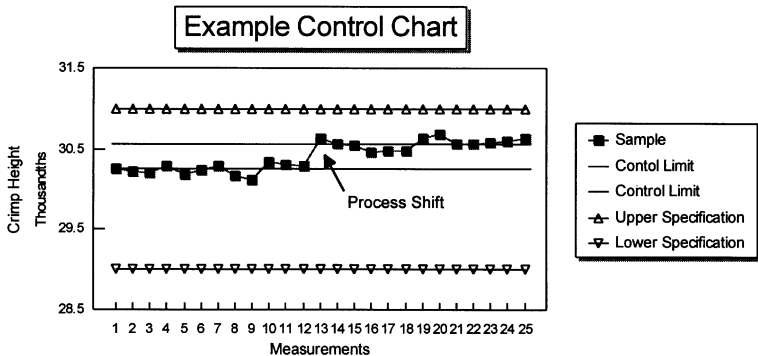
7.3 VISUAL INSPECTION

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

7.4 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 & R Chart

Control Limit for sample of 5 = Avg (Avg of 5 readings) + .577 x 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 justify if an adjustment to the process is needed.

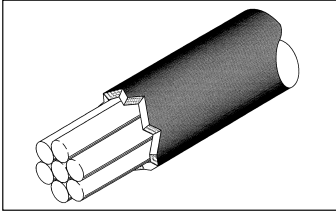


Figure 16 - Irregular Insulation Cut

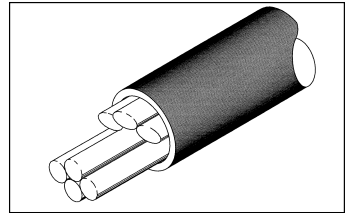


Figure 17 - Cut Strands

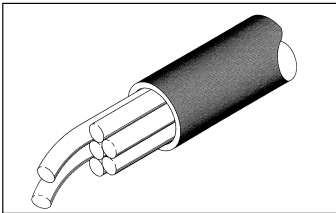


Figure 18 - Pulled Strands

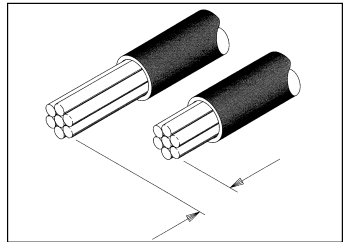


Figure 19 - Wire Length Variability or Wrong Strip Length

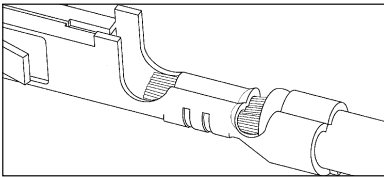


Figure 20 - Optimal Crimp

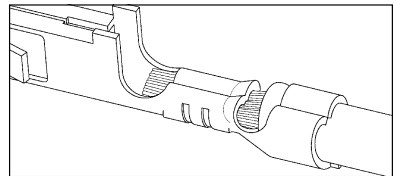


Figure 21 - Excessive Bellmouth

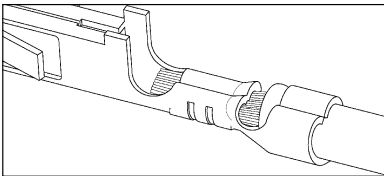


Figure 22 - Excessive Bellmouth, No Cut-off Tab

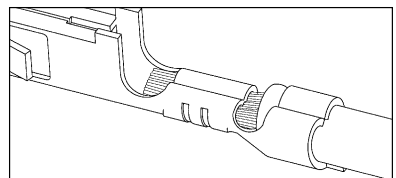


Figure 23 - No Bellmouth, Excessive Cut-off Tab

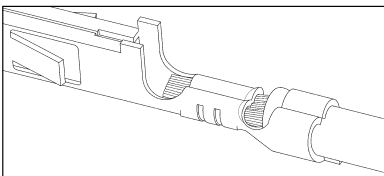


Figure 24 - Excessive Cut-off Tab, Good Bellmouth

8.0 TROUBLE SHOOTING



8.1 WIRE PREPARATION

Problem	Cause	Solution
Irregular Insulation Cut (Fig. 16)	Worn tooling Cut depth too shallow	Replace tooling Adjust cut depth

Cut or nicked strands (Fig. 17)	Damaged tooling	Replace tooling
	Cut depth too deep	Adjust cut depth
	Conductor not on wire center	Contact wire supplier

Irregular conductor cut - pulled strands (Fig. 18)	Worn tooling	Replace tooling
	Wire cut depth too shallow	Adjust cut depth

Wire length variability too high (Fig. 19)	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 (Fig. 19)	Incorrect setup	Re-setup tooling
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8.2 BELLMOUTH AND CUT-OFF TAB LENGTH

Problem	Cause	Solution
Low pull force (Fig. 21 & 22)	Excessive bellmouth no cut-off tab	Adjust track position for small cut-off tab
	Excessive bellmouth, cut-off tab alright	Check for worn or incorrect punch tooling and replace

Cut or nicked strands (Fig. 23)	No bellmouth and/or excessive cut-off tab	Adjust track position
		Check for camber in terminal strip

Long cut-off tab (Fig. 24)	Good bellmouth and excessive cut-off tab	Check for worn cut-off and replace if necessary
		Check for worn punch tooling, replace, and re-adjust track

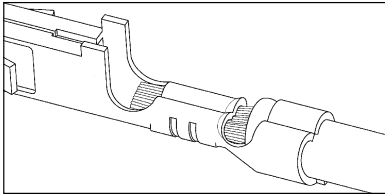


Figure 25 - Optimal Crimp

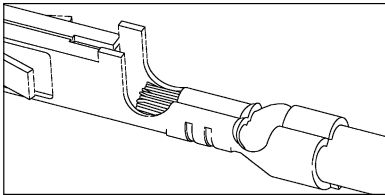


Figure 27 - Insulation Under Conductor Crimp, Conductor Brush Too Long

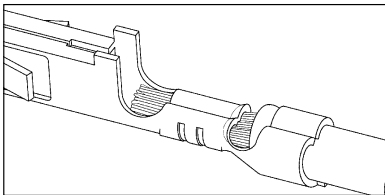


Figure 29 - Conductor Brush Too Long

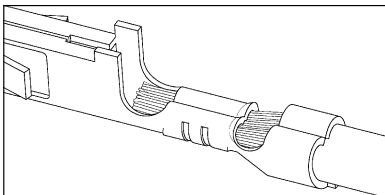


Figure 31 - Insulation Under Insulation Crimp, Conductor Brush Too Long

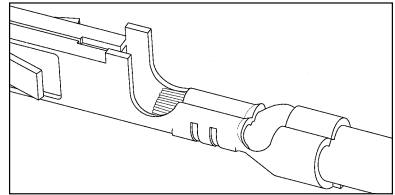


Figure 26 - Insulation Under Conductor Crimp, Good Conductor Brush

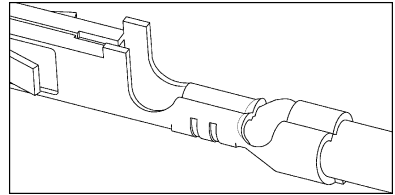


Figure 28 - Insulation Under Conductor Crimp, Short or No Conductor Brush

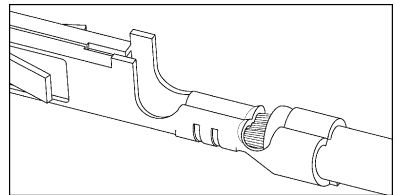


Figure 30 - Conductor Brush Too Short

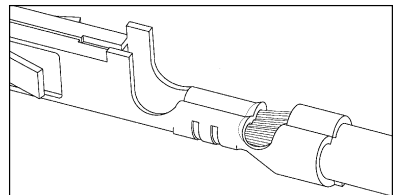


Figure 32 - Insulation Under Insulation Crimp, Conductor Brush Too Short

8.0 TROUBLE SHOOTING



8.3 CONDUCTOR BRUSH AND INSULATION POSITION

Problem	Cause	Solution
Insulation under cond. crimp, good conductor brush (Fig. 26)	Strip length too short	Check specification, adjust strip length longer
Insulation under conductor crimp, long conductor brush length (Fig. 27)	Bench - 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 (Fig. 28)	Strip length too short	Check specification, adjust strip length longer Re-adjust wire stop position for bench applications OR
		Re-adjust press position for wire processing applications
Insulation edge centered in transition area, conductor brush too long (Fig. 29)	Strip length too long Irregular wire cut-off or strands pulled from insulation bundle	Check specification, adjust strip length shorter
		Re-adjust wire stop position for bench applications OR Re-adjust press position for wire processing applications
		Check for worn stripping tooling
Insulation edge centered in transition area, conductor brush too short (Fig. 30)	Strip length too short	Check specification, adjust strip length longer Re-adjust wire stop position for bench applications OR
		Re-adjust press position for wire processing applications
Insulation edge under insulation crimp, good or long conductor brush (Fig. 31)	Strip length too long	Check specification, adjust strip length shorter Re-adjust wire stop position for bench applications OR
		Re-adjust press position for wire processing applications
Insulation edge under insulation crimp, short or no conductor brush (Fig. 32)	Bench - 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

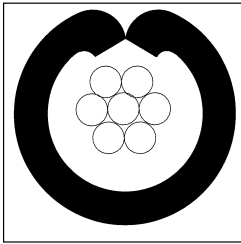


Figure 33 - Preferred Insulation Crimp

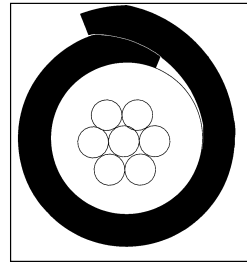


Figure 34 - Preferred Insulation Crimp

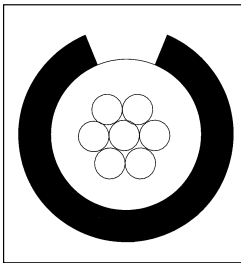


Figure 35 - Acceptable Insulation Crimp

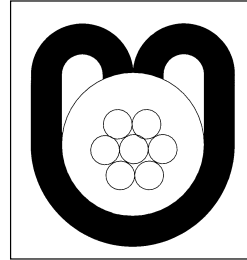


Figure 36 - Acceptable Insulation Crimp

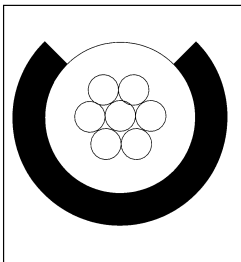


Figure 37 - Marginal Insulation Crimp

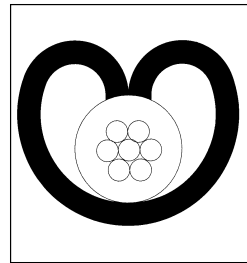


Figure 38 - Marginal Insulation Crimp

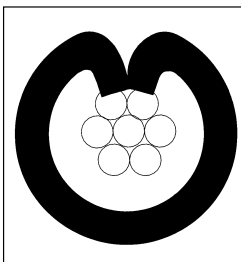


Figure 39 - Marginal Insulation Crimp

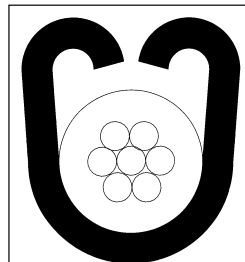


Figure 40 - Marginal Insulation Crimp

8.0 TROUBLE SHOOTING



8.4 INSULATION CRIMP

Problem	Cause	Solution
Terminal surrounds less than 88% of a large diameter wire (Fig. 37)	Crimp too loose, not enough terminal insulation barrel	Tighten insulation crimp height Evaluate terminal
Terminal contacts less than 50% of a small diameter wire (Fig. 38)	Too much terminal insulation barrel	Evaluate terminal
Insulation crimp barrels cut through insulation into conductor strands (Fig. 39)	Crimp too tight	Adjust insulation crimp height*
Insulation not firmly gripping insulation, fails bend test (Fig. 40)	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 criteria 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.

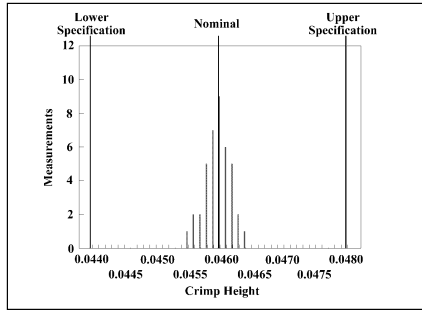


Figure 41 - Optimal Crimp Height Chart

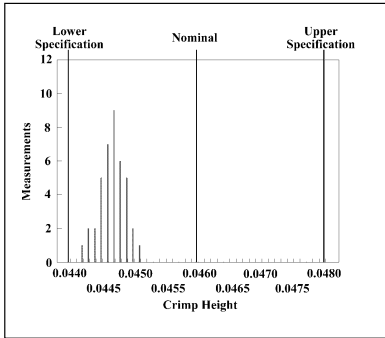


Figure 42 - Crimp Height Off Target

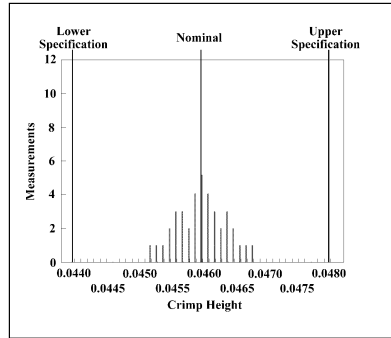


Figure 43 - Crimp Height Variability Too High

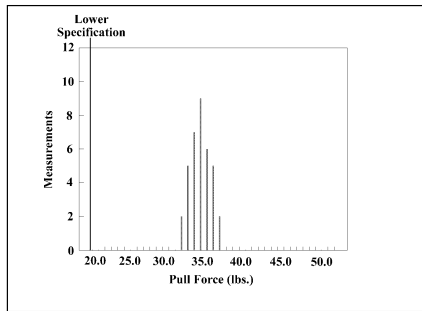


Figure 44 - Optimal Pull Force Chart

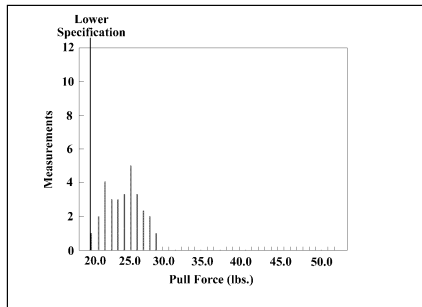


Figure 45 - Low Pull Force Chart

8.0 TROUBLE SHOOTING



8.5 CRIMP HEIGHT

Problem	Cause	Solution
Crimp height off target (Fig. 42)	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	
	Damaged or worn tooling	

Crimp height variability to high (Fig. 43)	Wire variability	Inspect incoming product.
	Terminal variability	
	Damaged, loose, or worn tooling	Tooling replacement or tightening
	Measurement error	Gage capability analysis
	Terminal spring back too great, over crimping	Crimp height adjustment
	Cut or missing wire strands	Stripping process adjustment

8.6 PULL FORCE

Problem	Cause	Solution
Wire breaks before conductor crimp - low pull force (Fig. 45)	Cut or nicked strands	Check the stripping process
	Crimp height too low	Adjust crimp height
	Small or no bellmouth	Adjust tooling track
	Insulation crimp through insulation wall	Raise insulation crimp height

Wire pulls out of conductor grip - low pull force (Fig. 45)	Crimp height too high	Adjust crimp height
	Small or no conductor brush	Increase strip length
	Conductor bellmouth 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



9.0 Wire Gauge Chart

AWG	WIRE AREA		STRANDING		WIRE DIAMETER		CIRCULAR	WIRE BREAK	
	sq. inch	sq. mm	#	dia.	inch	mm		MILLS	lbs.
8	0.01287	8.302	1	0.1280	0.128	3.25	16384	489.0	2175.00
8	0.01212	7.820	19	0.0285	0.145	3.68	15433	460.6	2048.72
8	0.01233	7.955	49	0.0179	0.147	3.73	15700	468.6	2084.21
8	0.01334	8.605	133	0.0113	0.147	3.73	16983	506.9	2254.49
8	0.01319	8.513	168	0.0100	0.147	3.73	16800	501.4	2230.22
8	0.01306	8.424	665	0.0050	0.147	3.73	16625	496.2	2206.99
10	0.00816	5.261	1	0.1019	0.102	2.59	10384	309.9	1378.44
10	0.00735	4.740	37	0.0159	0.115	2.92	9354	279.2	1241.75
10	0.00776	5.006	49	0.0142	0.116	2.95	9880	294.9	1311.63
10	0.00825	5.320	105	0.0100	0.116	2.95	10500	313.4	1393.89
12	0.00513	3.308	1	0.0808	0.081	2.05	6529	194.8	866.69
12	0.00563	3.632	7	0.0320	0.096	2.44	7168	213.9	951.56
12	0.00478	3.085	19	0.0179	0.093	2.36	6088	181.7	808.16
12	0.00511	3.294	65	0.0100	0.095	2.41	6500	194.0	862.88
12	0.00514	3.3118	165	0.0063	0.095	2.41	6549	195.5	869.37
14	0.00323	2.082	1	0.0641	0.064	1.63	4109	122.6	545.45
14	0.00352	2.270	7	0.0253	0.073	1.85	4481	133.7	594.81
14	0.00301	1.941	19	0.0142	0.073	1.85	3831	114.3	508.59
14	0.00322	2.078	41	0.0100	0.073	1.85	4100	122.4	544.28
14	0.00327	2.112	105	0.0063	0.073	1.85	4167	124.4	553.24
16	0.00203	1.308	1	0.0508	0.051	1.30	2581	77.0	342.58
16	0.00222	1.433	7	0.0201	0.060	1.52	2828	84.4	375.43
16	0.00191	1.229	19	0.0113	0.058	1.47	2426	72.4	322.07
16	0.00204	1.317	26	0.0100	0.059	1.50	2600	77.6	345.15
16	0.00203	1.307	65	0.0063	0.059	1.50	2580	77.0	342.48
16	0.00206	1.330	105	0.0050	0.058	1.47	2625	78.3	348.47
18	0.00128	0.823	1	0.0403	0.040	1.02	1624	48.5	215.60
18	0.00139	0.897	7	0.0159	0.048	1.22	1770	52.8	234.93
18	0.00126	0.811	16	0.0100	0.047	1.19	1600	47.8	212.40
18	0.00149	0.963	19	0.0100	0.049	1.24	1900	56.7	252.23

9.0 Wire Gauge Chart



AWG	WIRE AREA		STRANDING		WIRE DIAMETER		CIRCULAR	WIRE BREAK	
	sq. inch	sq. mm	#	dia.	inch	mm		MILLS	lbs.
18	0.00128	0.825	41	0.0063	0.047	1.19	1627	48.6	216.03
18	0.00128	0.823	65	0.0050	0.047	1.19	1625	48.5	215.72
20	0.00080	0.519	1	0.0320	0.032	0.81	1024	30.6	135.94
20	0.00087	0.563	7	0.0126	0.038	0.97	1111	33.2	147.53
20	0.00079	0.507	10	0.0100	0.035	0.89	1000	29.8	132.75
20	0.00096	0.616	19	0.0080	0.037	0.94	1216	36.3	161.43
20	0.00081	0.523	26	0.0063	0.036	0.91	1032	30.8	136.99
20	0.00081	0.519	41	0.0050	0.036	0.91	1025	30.6	136.07
22	0.00050	0.324	1	0.0253	0.025	0.64	640	19.1	84.97
22	0.00055	0.355	7	0.0100	0.030	0.76	700	20.9	92.93
22	0.00059	0.382	19	0.0063	0.031	0.79	754	22.5	100.11
22	0.00051	0.329	26	0.0050	0.030	0.76	650	19.4	86.29
24	0.00032	0.205	1	0.0201	0.024	0.61	404	12.1	53.63
24	0.00035	0.227	7	0.0080	0.023	0.58	448	13.4	59.47
24	0.00031	0.201	10	0.0063	0.024	0.61	397	11.8	52.69
24	0.00037	0.241	19	0.0050	0.023	0.58	475	14.2	63.06
24	0.00031	0.200	41	0.0031	0.023	0.58	394	11.8	52.31
.26	0.00020	0.128	1	0.0159	0.016	0.40	253	7.5	33.56
26	0.00022	0.141	7	0.0063	0.021	0.53	278	8.3	36.88
26	0.00020	0.127	10	0.0050	0.020	0.51	250	7.5	33.19
26	0.00024	0.154	19	0.0040	0.019	0.48	304	9.1	40.36
28	0.00012	0.080	1	0.0126	0.013	0.32	159	4.7	21.08
28	0.00014	0.089	7	0.0050	0.015	0.38	175	5.2	23.23
28	0.00014	0.093	19	0.0031	0.016	0.41	183	5.4	24.24
30	0.00008	0.051	1	0.0100	0.010	0.25	100	3.0	13.28
30	0.00009	0.057	7	0.0040	0.012	0.30	112	3.3	14.87
30	0.00009	0.060	19	0.0025	0.012	0.30	118	3.5	15.64
32	0.00005	0.032	1	0.0080	0.008	0.20	64	1.9	8.50
32	0.00005	0.034	7	0.0031	0.008	0.20	67	2.0	8.93
32	0.00006	0.039	19	0.0020	0.009	0.23	76	2.3	10.09



QUALITY CRIMPING HANDBOOK

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Corporate Headquarters : 2222 Wellington Court, Lisle, IL, 60532, U.S.A., Tel : 630-969-4550

Application Tooling Division : 1150 E. Diehl Rd., Naperville, IL 60563, Tel : 630-969-4550

European Headquarters : Munich, Germany, Tel : 49-89-413092-0

Far East North Headquarters : Kanagawa, Japan, Tel : 81-462-2336

Far East South Headquarters : Jurong Town, Singapore, Tel : 65-268-6868