Crimp Quality Standards Comparison and Trends

By Rob Boyd, Crimping Product Manager

Quality standards are getting tougher each year. In these difficult times, wire harness manufacturers are looking to expand business in their existing markets and are looking for new markets. The following article will compare and contrast the current quality standards that are most commonly used today. I will review proper measurement techniques, discuss some trends in crimp quality, and address methods to improve efficiency in quality data collection.

It goes without saying that manufacturing companies want top notch quality at the lowest possible price. All too often, they demand higher quality at the same or lower price. There are so many standards to adhere to and each manufacturer might have different requirements. Not only do we need to keep track of the numerous standards in the US but now that US companies are bidding for European jobs, we need to understand the European standards as well. Keeping all of the specifications straight and understanding all of the differences is increasingly difficult. We've also experienced situations where manufacturing companies had differences of opinion on what their own internal standards were. Larger companies with multiple plants, possibly in multiple countries are most susceptible to these kinds of challenges. Another consideration in these cases is language barriers. Different operators may take the same measurement differently and come out with different results. So who is correct? These issues make data collection more difficult and as we all know, data collection can be a very time-consuming and inefficient process if not done correctly.

UL 486A-486B is probably the most widely used standard and covers terminal and connector requirements for US, Canada and Mexico. The most specific standard for wire harness makers is the IPC/WHMA-A-620 standard, covering everything from crimping and soldering to lacing and tie wrapping. The IPC/WHMA-A-620 was a collaborative effort between IPC and the Wire Harness Manufacturer's Association. SAE AS7928, formerly MIL AS7928 and USCAR-21 are for military and automotive crimp connections, respectively. Both standards were created by the Society for Automotive Engineers. The most recent automotive specification is the VW 60330 which is the only process-oriented specification indicating how often testing should be done. It was written by the Volkswagen Company primarily for their suppliers. Each standard has their subtle differences. When you have some manufacturing companies who want products made to the UL spec and others who want products made to SAE specs, how do you keep track of the differences?

Much of the discussion to come will reference the automotive specifications. However, as quality standards get tighter, some of these standards may be adopted by other markets. I'm going to highlight a few of the differences between the tools and measurement techniques for crimp height and pull test and also mention micrograph (cross sectioning) equipment.

Crimp Height and Crimp Width

The only thing that all of the specifications have in common is that they all state that the terminal manufacturer's specifications for crimp height and crimp width must be used. Only the A-620 specification makes crimp height measurement optional. It is optional only when pull testing is done. Only the VW specification states that 5 samples must be tested for each set-up. A set-up is when the wire, terminal, terminal reel, or applicator tooling is changed.

The VW and A620 specifications states that for crimp height measurements, a micrometer with a point and a blade (Fig. 1) must be used. The reason is to eliminate the possibility for the flash to affect the measurement (Fig. 2). However, this method is not perfect either. If the measurement is not taken at the highest point of the crimp, the measurement may be incorrect.

Figure 1

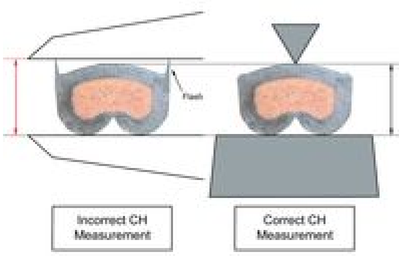

Figure 2

Crimp width is a bit of a challenge. Most companies don't measure crimp width because it is a fixed dimension in the tooling. The only specifications that really address it are VW and USCAR and they both use different terminology. They state that there are two crimp widths; one can be measured on the crimped terminal and the other cannot (Fig 3). The "Crimp Width" (VW) or "Tangent Width" (USCAR) is the non-measureable crimp width. It is a dimension on the crimp tool at the top just where the rolled part goes to the straight sides of the tool. Technically it is between the tangents of the radii of the crimp die. The "Measurable Crimp Width" (VW) or the "Crimp Width" (USCAR) is measured at the widest point of the terminal. VW states that a 2-blade tool must be used to determine the measurable crimp width. The other specifications do not state requirements on tooling. Although I am mixing terminology from different specifications, for the purpose of this article I'm going to use the terms "Crimp Width" and "Measurable Crimp Width" for clarity as shown in Figure 3.

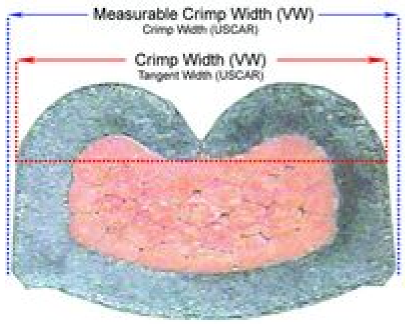

Figure 3

Tolerances are sometimes an issue as well. Some of the terminal manufacturers indicate tolerances for crimp height but some don't. Some companies will use their own tolerances but some employees will apply them differently. Only USCAR and VW indicate tolerance specifications depending on the wire size. As you will see in the chart below, tolerances are the same but the corresponding wire sizes differ.

Wire Size	**Tolerances** **Conductor Crimp Height (CCH)**
USCAR	
≤ 0.35 mm²	± 0.03 mm
> 0.35 mm²	± 0.05 mm
≥ 8.0 mm²	± 0.10 mm
VW 60330	
0.22 – 0.5 mm	± 0.03 mm
0.5 – 2.5 mm	± 0.05 mm
> 2.5 mm	± 0.10 mm

Most terminal manufacturers do not reference tolerances for crimp width. This can be challenging because as we all know, tooling wears. So what tolerance is used? The VW specification uses a ±0.10mm for crimp width. The others do not address it.

The crimp width tolerance is usually not listed in terminal specifications because it usually refers to the tangent width, which is the non-measurable crimp width. It is used as a tooling reference, not as a quality measurement parameter. Some manufacturing companies use this for the measureable crimp width dimension but this isn't technically correct. The sides of the crimp tooling are angled (i.e. 3° or 4°) which means the tangent width is less than the measurable crimp width. Therefore, how do companies verify that the crimp width conforms to the manufacturer's specification if 1) the specification given cannot be measured, 2) there is no dimension for the part of the terminal that can be measured and 3) there are no tolerances for the listed dimension? What are companies measuring and is it really correct?

Pull Test

Pull test is discussed in all of the specifications and it is mandatory in all of them except the IPC/WHMA-A-620. The A-620 states that if crimp height measurements are taken, then pull test is not required. The A-620 also specifies that any samples that are used for pull testing cannot be used as finished goods.

Pull test rates vary between specifications as well. Pull rate is the rate at which the wire and the terminal are pulled apart. It can be important because different values may be achieved if pull rates are not consistent. Usually, higher pull test values can be achieved with higher pull rates. The UL and VW specifications do not specify a rate, so manufacturers can use the fastest method available as long as there is no sudden jerking on the sample. USCAR specifies a rate between 50 – 250 mm per minute, but 100 mm per minute is preferred. The SAE AS7928 specifies a pull rate of 1" per minute.

When performing a pull test, most manufacturing companies do not remove the insulation crimp. However, the VW, UL and USCAR specifications require that the insulation crimp is opened up or rendered ineffective. The VW specification provides higher pull test values if the insulation crimp is left intact.

USCAR is challenging to adhere to in that it specifies that the device used for testing must be capable of a tolerance of ± 1% of the measurement value. Most pull test device tolerances are stated with respect to their maximum pulling force. According to USCAR, a 24 AWG wire has a minimum pull force of 40 N (8.8 lbs). A tolerance of ± 1% of the measurement value would be 0.4 N (0.09 lbs). To comply with USCAR you could not use the standard 110 lb (500 N) pull test devices unless it had an accuracy of better than 0.09%. Most have accuracy of 0.5% or 0.25% of the maximum pull force, which is far from 0.09%. Stated another way, in order to achieve a tolerance of 0.4 N for the 24 AWG wire test, the pull tester could have a maximum pull force of 17.6 lbs (80 N) if the device had an accuracy of 0.5%. If the device had an accuracy of 0.25% the maximum would be 35.2 lbs (160 N). The smallest wire that could be tested on a 110 lb pull tester according to USCAR would be 12 AWG. Therefore, wire harness manufacturers that must comply to USCAR will either need pull test devices with extreme accuracy or they will need many devices for a complete range of wires. A wire range from 10 AWG to 22 AWG would require 5 different pull test devices.

Micrographs

Even with all of these standards, 25% of all electrical failures in a car (and possibly in other products as well) are due to bad crimps. Aside from simple mistakes made during the harness manufacturing process, terminals can go out of tolerance in the manufacturing process and frequently companies need to use terminals that are too large for the wire.

The following is an example (Fig 4) of a terminal that is rated for a wire range of 26 AWG to 20 AWG. The wire used is a 26 AWG and the crimp height and width is as specified by the manufacturer. The air gaps inside the crimp clearly indicate that the terminal is too big for the wire.

Figure 4

USCAR recognizes that not all wires are the same. A 0.5 mm² wire made to the SAE specification (0.508 mm² minimum) is different from a 0.5 mm² made to the ISO specification (0.4647 mm² minimum). Because of issues such as this and the persistence of crimp quality problems, more and more companies, like VW in Europe and China, are integrating crimp cross section analysis into their production processes.

Micrograph systems, or crimp cross sectioning equipment, were typically only seen where applicator tooling was manufactured or in the labs of the large wire harness suppliers. They were large table units involving epoxies and acidic etching solutions. The systems typically cost $50,000 or more and entire process was very time consuming. On the other hand, this type of equipment is the only way to get a clear picture of the inside of the crimp (Fig 5).

Figure 5

New systems on the market are much more suited for use in the production process because the crimp analysis process is much faster since there are fewer steps. Most systems use an electrolytic staining process rather than acid etching. Acids require special training, gloves and eye protection as well as special procurement and waste processes, since acids are considered to be hazardous materials. The solutions in the new systems have a Ph value equal to that of water so they are much safer to use and no special procurement and waste processes are required. Finally, the new systems are far less expensive. Therefore, getting a comprehensive analysis on the entire crimp is faster, easier and less expensive.

Only the USCAR and the VW specifications discuss the use of micrograph systems. The USCAR specification identifies them as only diagnostic tools for resolving issues. The VW specification mandates their use depending on wire size. More issues are seen in smaller wire sizes, so testing frequency is higher. The table below indicates the frequency requirements as stated in the VW specification.

Wire Size		**Test Requirement**
≤ 0.35 mm²	all	- when changing terminal reel
		- when changing the cable supplier
0.5 mm²	- signal lines:	- as on ≤ 0.35 mm²
	- power lines:	- as on ≥ 0.5 mm²
≥ 0.5 mm²	all	- after 1/6th lifetime of the crimping tool
		- on new contacts, where lifetime is unknown: every 30.000 cycles

Below is a sketch from the VW specification indicating all of the required measurements (Fig 6).

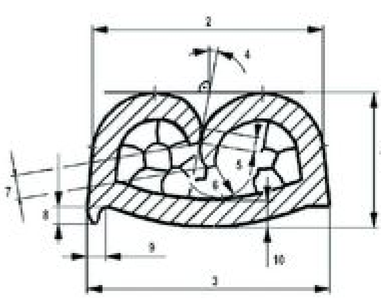

Figure 6

The crimp height (1) is the standard measurement. The crimp width (2) or the non-measurable crimp width can only be measured using a micrograph. The measurable crimp width (3) is simply taken at the widest point of the terminal. The support angle (4) and support height (5) are indications of how centered the terminal is in the crimp and how strong the crimp will be over time. The more vertical the angle is and the larger the height is the stronger the crimp will be over time. The face end clearance (6) is an indication if the terminal is properly sized to the wire. If the terminal is too large, the face ends may touch or be too close to the bottom of the crimp. The distance between face ends (7) is also an indication of how centered the terminal is in the crimp. Burr height (8) and burr width (9) are indications of crimp anvil wear. Finally, base thickness (10) is an indication if the material has been over-crimped. The VW specification gives guidelines for each value indicating acceptable limits.

Micrographs are also very useful when verifying terminal bend angles (Fig 7) and cross area reduction. Both of which are very difficult to measure without a micrograph system.

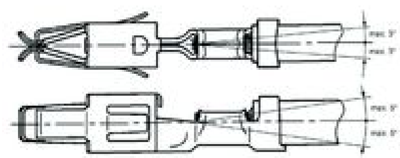

Figure 7

Quality standards are getting more rigid each year. Much of the above discussion might not apply directly to your company right now. However, we've seen in the past that standards that begin in one industry eventually migrate to others. Therefore, hopefully this gives you some advanced warning about what might be needed in the future. The preceding discussion covered a very small percentage of the respective specifications, but hopefully this has given you a better understanding of the different specifications and how they may be applied in your business. For more information on the respective specifications, please go to:

UL 486A/486B	www.ul.com
USCAR 21	www.uscar.org
IPC/WHMA-A-620	www.ipc.org
SAE AS7928	www.sae.org