

IHI Brand, IHI Connectors[®] / International Hydraulics Inc. SMT Surface Mount Technology. Precautions before choosing SMT wire terminations. FAQ.

The increase in the use of SMT high density logic “micro” circuits has also increased the use of multi layer PCB architectures. At the same time, really high currents are now routinely handled on PCBs where high current power can be controlled and switched using semi-conductors for numerous traditional and new applications in renewable energy, energy storage and conversion, and many other commercial and industrial control applications.

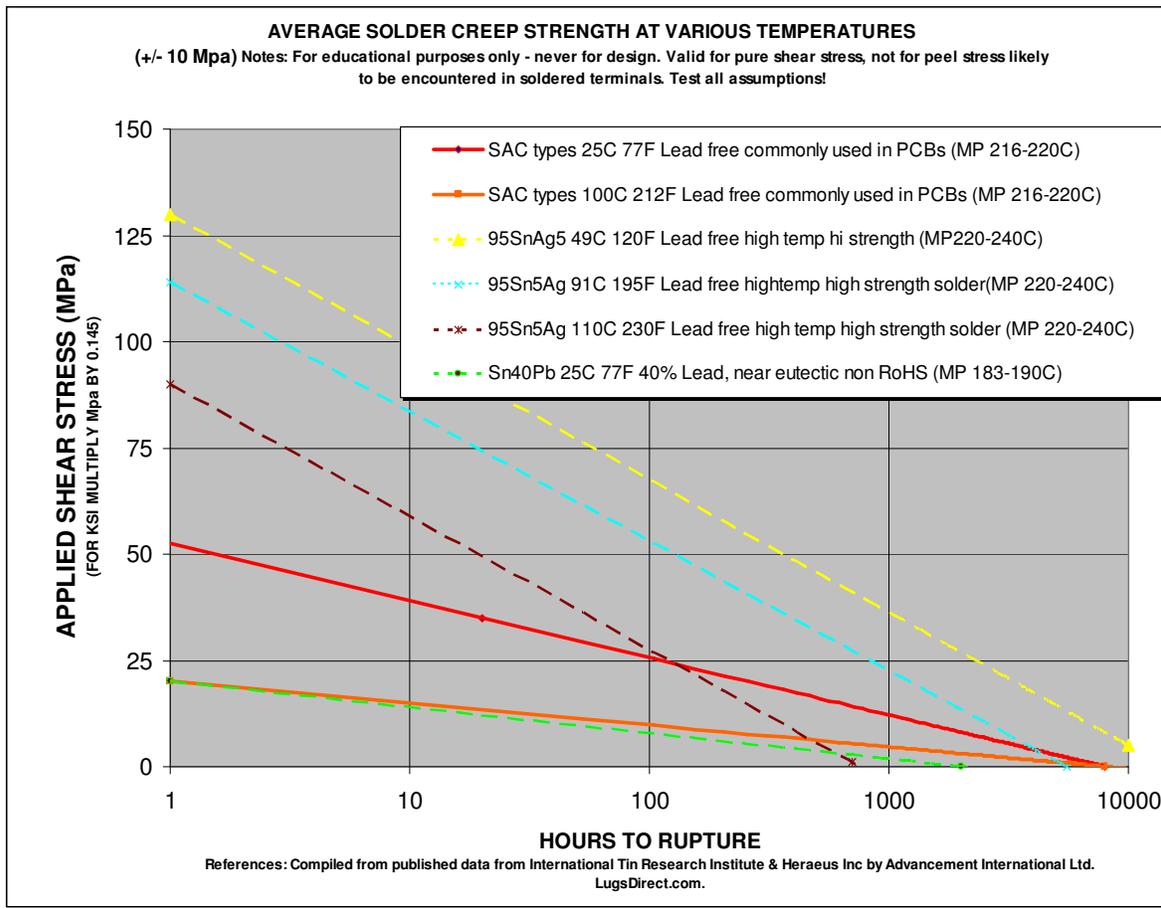
There are serious challenges to use of SMT methods for high current, large wire terminations which need to be fully understood by the customer when using SMT in place of THT (Through Hole Technology) to terminate high current wires, on the PCB.

After more than 12 years of experience shipping High Current THT technology, IHI has SMT products which can be carefully evaluated by our customers’ engineers for applicability.

Surface Mount Technology by definition excludes mechanical bus pass through to the opposite side of the PCB which reduces mechanical and electrical fortitude versus THT, and consequently requires CAREFUL DERATING, SAFETY REVIEWS, and PRODUCT LIFE REVIEWS for each customer application on its own merits. There is no shortcut for thorough testing by your design team in the assembled form in the worst case situations, to ensure all of your assumptions are good. Given your obligation to do the due diligence testing on your particular application for durability and safety covering all possible scenarios, we have included some test formats that may be helpful as part of your total design review program.

Some guidelines rules for use of SMT (Surface Mount Technology) in place of THT (Through Hole Technology) for PCB terminals. This is not by any means a full listing but a starting point for a complete engineering study developed by your team.

1. Always use THT as the first option. Do not use SMT unless you take responsibility to investigate the increased limitations and fully safeguard for them.
2. For SMT applications, solder alone is a poor mechanical joint – creep (movement) under small constant loads is significant (consult tin creep chart below). So long term loading (pull, push or twist) of soldered SMT terminals is a no-no.
No constant loads are to be applied to the SMT terminal – all wires must be separately anchored elsewhere. The weight of wire or other forces hanging on the SMT terminal must be close to zero.
3. Avoid field wiring applications if the anchoring of the wire is up to the end user. You must be to know that the adequate anchoring of the wire is going to happen.
4. Anchor by default, like building the wire anchor into the case or so that the wire is fully clamped on the insulation when re-attaching the cover rather than expecting the end user to use a wire tie and not bothering to do so. Make sure wire anchors meet the wire pull forces that could be encountered.



- Do full maximum current (or better, elevated over full current) heat rise and heat cycle tests to rule out fatigue of the solder joint caused by differential expansion and contraction between copper and aluminum. This phenomenon limits the maximum size of aluminum terminal that can be used with copper foils. The higher the heat range encountered at high cycles the more likely there is to be some stresses develop. All mechanical tests need to be done before AND AFTER a long term cycle high current stress test.

Following the format of UL486A-B where the testing method for aluminum wire in wire terminals is comprised of a 500 on, and 500 off, over-current cycles and should be a good starting point.

If your application is heavily cycled in terms of current and temperature then you must consider that in the evaluation process.

Typically for small light parts, 30 minutes is adequate to get the part up to full temperature and then another 30 minutes to get back near room temperature. The time for the duration of each cycle has to be sufficient to allow the maximum and ambient stable temperature to be reached with each cycle. If the temperature has not leveled off then use a longer time. A total time commitment of 500 hours or three weeks of 24/7 testing or longer.

Longer term testing should be done if any adverse signs show up or if the product will see rougher service in terms of current, number of cycles, harsh environment and other factors

known to the customer. Use of fine stranded (flex) wires can increase chances of joint relaxation, wire oxidation and therefore hotter running over time and cycles.

Test Currents: UL486 uses 1.60-1.65 times the continuous NEC 75C rated current for the wire used to carry out 500 cycle tests for COPPER wires.

To achieve NEC 90C current rating the test current is 2-2.5X the user current for copper wires. Bear in mind when attaching a terminal with solder to a PCB, rather than bolting it to full size copper bus, heat rises will likely be higher or much higher. Foil is a lot thinner than a typical electrical bus. Trace widths will not likely make up the deficit.

As a guide to the elevated test currents for industrial type electrical gear these are for 75C and 90C wire insulation (and therefore user current rating) respectively

AWG#10 rated at 30A in use, 500 cycle test at 56A (90C rating test at 75A)

AWG#8 rated at 50A in use, 500 cycle test at 80A (90C rating test at 100A)

AWG#6 rated at 65A in use, 500 cycle test at 105A (90C rating test at 131A)

AWG#4 rated at 85A in use, 500 cycle test at 140A (90C rating test at 175A)

AWG#2 rated at 115A in use, 500 cycle test at 190A (90C rating test at 240A)

Current STABILITY is as important as total heat rise since it speaks for the integrity of the electrical joints over time. The stability factor S_{each} should not exceed + or – 10 based on the STABILITY formula S_{each} for each of 11 readings = $d_{each} - D_{avg}$

$D_{avg} = (d_{each1} + d_{each2} + d_{each3} + \dots + d_{each11}) / 11$.

This test was originally conceived to test the integrity of aluminum wire in wire connectors. It is not required for copper wire only applications but nevertheless is a very good way to shake out issues that involve thermal cycles and the decay of integrity which can occur over time.

Readings are taken at cycle number 25, 50, 75, 100, 125, 175, 225, 275, 350, 425, and 500.

For electrical gear (all bolted metal construction, no soldered joints) the 500 cycle test is considered good if the heat rise is under 125C over ambient but clearly this is way, way hotter than any PCB should run and therefore is not a useful pass grade for PCB lugs and particularly SMT lugs.

6. Assuming that end customers do not torque the wire binding screw properly or some long term relaxation can occur (in particular for aluminum wire for which the 500 cycle test is designed) has lead UL to use a lower than standard user torque for 500 cycle testing. For assigned user torques (not those based on the type and size of driver tool) are lowered to 90% of the user torque for the 500 cycle test. For generic driver type torques (UL charts), the torque reduction can be much larger, say 20-30% (see UL486A-B).

IHI UL approved parts are shipped with specified (assigned) user torques to ensure that the user has the proper information about the correct UL file torques. No UL approved parts are subject to the development of the correct torque for a given customer application, wire size and class.

7. Static Heat Rise tests are a good place to start testing a design in order to find out what heat is being generated and dissipated in your assembly under the highest loads possible and worst cooling situations including high ambient temperature. Heat rise test temperatures are for “bolted” construction industrial bus situations so should be derated for PCB applications where FR4 and thin copper foils are likely to degrade over time (see heat cycle test) leading to higher thermal resistance from foil delamination. It is known that wave soldering (and other heat methods of soldering PCB components cause a lowering of the

heat flow through the PCB from a reduction of bond strength in foils and dielectric materials.

AWG10 user current 30A, heat rise test current 50A

AWG8 user current 50A, heat rise test current 70A

AWG6 user current 65A, heat rise test current 95A

AWG4 user current 85A, heat rise test current 125A

AWG2 user current 115A, heat rise test current 170A

In industrial electrical applications, the heat rise test is considered satisfactory if the rise in temperature over ambient is less than 50C. However for a PCB application, especially a SMT one, much lower heat rises would be indicated. A rule of thumb for printed circuits is that every 10 Degrees C increase in working temperature will halve the life of the PCB assembly.

8. By testing the twist off torques before and after the 500 cycles it should be possible to see the degree of strength loss and if that should be a concern for the particular application.
9. Solder has very low strength at modestly higher temperatures. Review yield strength charts for tin at elevated temperatures and in combination with creep load (which should not exist –see #2, #3).
10. Use terminals sized conservatively that will help to keep the joint cooler rather than using a terminal at the maximum current that NEC rates the size of wire and terminal. Say, use an AWG#4 wire and terminal (NEC rated 85A) at #6 current of 65A.
11. Use thicker foil on the PCB. The foil is the ONLY thing conducting current, creating extra local heat (thin sections) and retaining the terminal mechanically so clearly, a thicker foil is superior and the right and adequate thickness is mandatory.
Thicker foil helps the mechanical strength of the joint. There has to be some metal structure to do the job of distributing the load and heat and spread the torquing stresses more uniformly to the dielectric substrate.
12. Find out what the largest wire is going to be and then test the screw on wire retention force. IHI can give guidelines on the right area for a good wire connection to the terminal based. That user torque should then be increased by a safety factor and then the terminal should be subjected to that torque multiple times with no damage to the SMT joint. Some solder creep at extremities is not uncommon at high torques but is not an issue if it does not affect failure torque (negligible loss of joint strength).
13. Have proper and effective means to avoid overheating of the PCB for any and all reasons whatsoever. If the solder joint melts there is nothing else to hold it in place (other than the wire retaining anchor required for SMT). Design for that.
14. Solder joints must be checked for integrity by torque testing the terminal to failure. A minimum twist off failure torque must be established by the user of the SMT terminal and it must be controlled by the manufacturing facility that makes the PCB assemblies. A minimum wetted area and porosity (gas bubbles or localized spot dewetting from normal plating variations) of the sheared solder interface should be established along with the minimum shear off twist torque. These allowances may have to be liberal to account for normal variations in soldering in real world production conditions. A design which relies on 100% coverage on every joint is not realistic for production and indicates a marginal design doomed to poor yields and quality issues along with high hidden production costs.
15. Take full account of the fact that with SMT (not with THT) you lose the mechanical through-joint of the foot or feet that pass through the entire thickness of the PCB and also the current path enabling top and bottom foils to share the current and dissipate heat to air. Over sizing the SMT terminal and wire size for mechanical and current path and heat rise reasons is much more important on SMT than THT.

16. Porosity of solder joints in lead free solder is quite possible and will weaken the twist off torque considerably with no external evidence (nice wetted joint externally but reduced metal content internally from gas bubbles, spot dewetting and other voids).
17. Develop the right solder/flux paste recipe and process for your application proven by adequate testing. As with all soldering, process control is vital to consistent results.
18. Do tear off tests by leaning the SMT terminal over with a torque wrench and a crow's foot wrench to see at what force the copper foil peels away. This is especially important for SMT near the edge of the PCB where separation of the foil is more likely. The peel force must be adequate for the application and safety. Do it in both axes but look for lowest number in the shortest axis or one near the edge of the foil.
19. Position SMT terminal inboard to avoid the weaker and hotter running edge area of the PCB
20. Do pull UP tests to ensure that no weakness exists in that (less likely) fourth upward force plane.
21. PCB foil adhesion strength is known to fall after soldering due to the high temperatures of the soldering process (especially lead free) and stress on the organic dielectric plastic substrate.
22. Do what-if analysis for safety – if the SMT terminal “fell off” due to poor implementation of the joint, what would the consequences be? Must be fail safe – grounded, no person ever in danger, etc. never use in life support, vehicle braking systems, or any other human-in-danger scenario, meets all applicable safety codes and electrical codes.
23. Realize that you will need to hold the SMT terminal in place while soldering as it will float around on the melted solder otherwise.
24. The means to hold the SMT terminal in place must not cause movement during the solder solidification process which will seriously weaken any soldered joint. Typically a solder mask border will control the part from floating off location but it must be level and without shock, movement or vibration while solidifying.
25. IHI solderable body (one piece) SMT PCB terminals have limited solderability life at high temperatures due to high temperature migration of substrate metals causing a loss of wettability of the tin coating. While the high temperature time is adequate for wave soldering and flux paste soldering (or hand soldering with solder wire) it may not be for some high temperature, long duration, processes like reflow operations or some slow rework operations. These parts should be considered single use parts and not reused in rework situations.
26. IHI will reject all warranty claims caused by poor application design, inadequate failure mode analysis inadequate customer testing and inadequate process controls to maintain integrity and inadequate quality control to eliminate suspect SMT joints. If the joint fails in any way – the implementation was inadequate! In short all, (all) aspects of the connection integrity of the terminal to the PCB are the customer's responsibility to confirm before using!
27. Happy testing! A thorough test program and conservative design will help you make your customers happy with your products.