Technical Note

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Extending Soldering Iron Tip Life

Table of Contents

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Abstract

This Technical Note discusses the construction of solder tips, the various failure modes associated with tip plating (cracking, wear, corrosion, and dewetting), how to diagnose those failure modes, and specific practices that can be taken to minimize or eliminate each one.

In addition, care practices specific to Metcal and OKi tips and tip cartridges are given. OKi and Metcal products, using SmartHeat® technology, operate at lower temperatures while delivering the necessary amount of thermal energy directly to the load. Operating at lower temperatures is the answer to many of today's soldering process issues, including the reduction of tip plating failures.

Soldering Iron Tip Plating Failures

Even under normal usage, the plating on all soldering iron tips will eventually fail. Plating life is highly dependent on the soldering application, the type of fluxes and solder used, and—most importantly—operator technique. Because of this, manufacturers of soldering iron tips do not generally warrant plating life.

Tip plating failures for all solder tips can be divided into four main classes.

- Stress/Cracking
- Corrosion
- Dewetting
- Wear/Abrasion

Before discussing each of these in detail, it is useful to understand how a typical soldering iron tip is constructed.

Tip Plating

Figure 1 shows a plating diagram of a typical soldering iron tip.

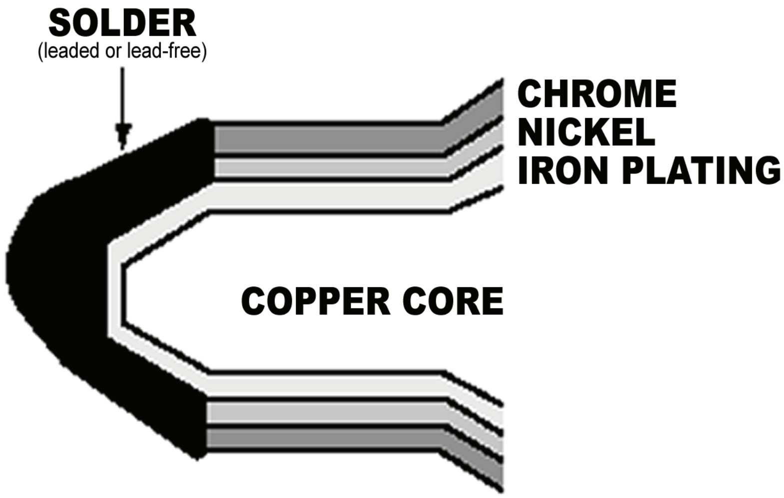


FIGURE 1: Soldering Iron Tip Cross-Section
(Not to Scale)

A tip typically consists of a solid copper core, a plated layer of iron, a plated layer of nickel behind the working surface, and a plated chrome layer. Copper is used for the core primarily to ensure good heat transfer. The nickel layer is a non-wetting layer designed to keep the solder from wicking away from the tip's working surface. Without this layer, the solder would travel preferentially up the tip toward the heat source, making it impossible to apply solder to the solder joint. The chrome layer is applied as an additional protective layer.

The key working layer, and the one that affects tip life the most, is the iron layer. Most plating failures are a failure of the iron. The iron fails in a different way for each failure mode. It is important to understand which failure mode is occurring, so that the proper corrective action can be applied. For example, it is common for people to believe that simply putting more iron on a tip will improve tip life. While applying more iron may help prevent wear-related failure, it would not help prevent dewetting or cracking the tip.

Iron, like any material, has its strong and weak points. Soldering iron tip manufacturers have investigated a number of alternative materials; however, to date, iron has had the best combination of properties for use in soldering applications. The specifics of this are discussed in the next section, "Why Iron Plating?"

Why Iron Plating?

Why has iron been chosen universally by all solder tip manufacturers as the working surface material for a solder tip? To answer this question, we must examine the material requirements for a solder tip.

Must Have Good Heat Transfer Properties

As transfer of heat is the primary task of a soldering iron, it is not surprising that a solder tip material must have good heat transfer properties. For the most part, this means that metals must be used (as opposed to ceramics, for example, which may have better mechanical properties but are thermally insulative). Iron has acceptable transfer properties, but copper is better (which is why solder tip cores are made of copper). So why not make copper solder tips?

Must Not Dissolve in Molten Solder

Lead-free solders are a ternary combination of tin, silver and a small amount of copper. Preceding lead-free requirements, most commercial solders were some binary or ternary combination of tin and lead. Molten tin will rapidly dissolve most metals, including copper. So a protective layer must be applied that won't dissolve so rapidly in tin. Iron is one of the few metals that can resist exposure to molten tin for any period of time. But molybdenum also resists tin dissolution and has even better mechanical properties than iron. So why not use molybdenum?

Must Be Wettable

The working surface of the tip must wet to transfer molten solder to the joint and to aid heat transfer. Iron wets. Molybdenum doesn't.

Must Have Good Physical/Chemical Properties

These include abrasion resistance, ductility (for crack resistance), melting point, etc. Iron, while not the best in any of these categories, has acceptable mechanical properties.

Must Be Processable

Iron can be applied to a copper substrate with good adhesion by a number of techniques. Electroplating is the most common method.

Conclusion

For today, iron best meets all of the above criteria.

Stress / Cracking Failures

Plating failure due to cracking is caused by too much stress being applied to the tip during soldering. Usually, operators apply too much pressure on the tip, mistakenly believing that applying more force to the tip will aid heat transfer. This is incorrect. The best ways to ensure good heat transfer are to use the largest tip possible on the lead that allows good access (maximize contact area), to tin the tip well, and to use molten solder as a thermal bridge between the tip and joint.

While iron plating has many good properties, fracture toughness is not one of them. Too much force applied to the plating layer will cause a crack to form. This crack will propagate all the way through to the copper core, in much the same way that cracking a block of ice causes the ice to split. Due to this crack propagation, a thicker plating of iron will not cure this problem.

Once the copper core is exposed, solder will quickly dissolve it away, hollowing out the tip (**Figure 2**). At some point, the iron plating, unsupported by copper, snaps. A sure sign of a stress/cracking failure is a hollowed out or jagged tip.

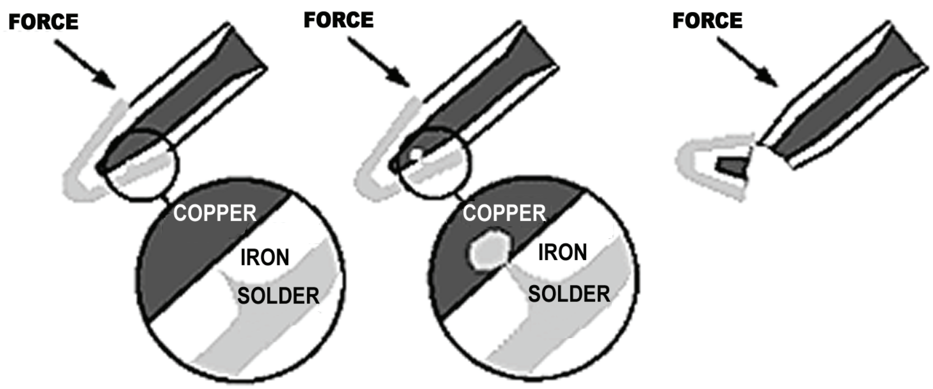


FIGURE 2: Pressure Failure

Banging the tip against a workstand is another way to crack iron plating. This can be prevented by taking care not to hit the tip against the workstand when reinserting the solder handle. To help guard against this problem, all Metcal and OKi workstands currently sold have phenolic plastic inserts. The softer plastic is more forgiving than metal should the tip accidentally strike it. However, even with plastic, a carelessly struck tip may still crack.

Cracked plating tends to be more common with fine point tips, which are more susceptible to the mechanical stresses that can lead to cracking. Wherever possible, the largest tip that maximizes contact area between tip and lead should be selected (**Figure 3**). This will maximize heat transfer, reducing the tendency to apply too much force to the tip. Also, larger tips can withstand more force.

FIGURE 3: Proper Size

Soldering iron tips can also be easily damaged when they are used for a job for which they were not intended. They should never be used for prying clinched leads, as a screwdriver, or as a can opener. There is a reason that pliers and screwdrivers—the proper tools for these jobs—are made of hardened steel alloys. Tips cannot withstand the harsh mechanical abuse these tasks entail.

Corrosion Failures

Corrosion induced plating failures are primarily related to the flux being used with the solder. Iron, like many metals, can be attacked when exposed to acids. Fluxes generally contain some form of halide additive or organic acid material. They are designed to chemically strip away iron oxides when brought to soldering temperatures. Unfortunately, some of the more active fluxes will also attack iron. One common class of fluxes, aqueous clean fluxes, appears to cause a high incidence of corrosion failures, since they are highly active and typically contain an organic acid (like citric acid). However, flux chemistry varies greatly according to manufacturer. Consult your flux, solder wire, or solder paste supplier for more details.

When selecting a flux, you should not only take into account long-term solder joint reliability, post assembly cleaning costs, in-process effectiveness, environmental considerations, etc. You should also take into account the effect on solder tip life, which has a direct bearing on operating costs.

Strictly from the standpoint of tip plating corrosion, the less active the flux, the lower the chance that the plating will be eaten away. (For a discussion on No-Clean solders, see *Appendix A*). **Figure 4** shows an activity ranking of various flux types. RMA fluxes have proven to yield the best tip life.

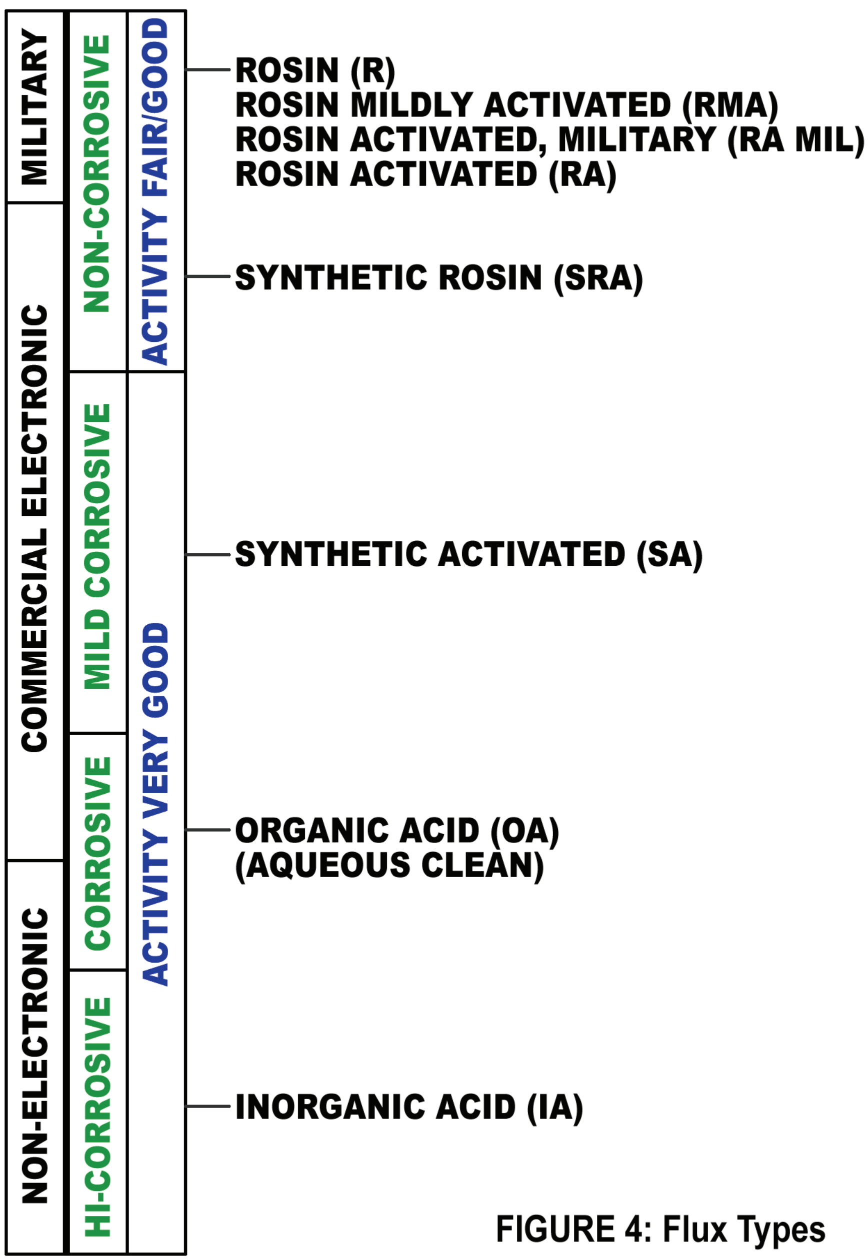


FIGURE 4: Flux Types

Corrosion related failures can further be reduced by making sure sponges used to clean tips are sulfur free. Only use sponges carried by a reputable solder supplier designed for soldering. Regular "store" sponges often contain sulfur or plastic materials that form corrosive by-products when the sponges are heated to soldering temperatures.

Use only clean sponges. Dirty sponges collect contaminants which can react at high temperature, forming corrosive by-products.

Also, when tinning a tip for storage, use an RMA or other low activity flux core solder. Do not use aqueous clean or organic acid flux core solders, as these can corrode the tip during storage.

Dewetting Failures

Dewetting is the most common form of plating failure and is preventable, for the most part, with good daily tip care. Thermal dewetting is caused by oxidation of the iron plating to iron oxide. Iron oxide is non-wetting. A dewetted tip can be identified by the fact that solder will not flow evenly across the working surface of the tip. Instead, solder applied to the tip will tend to ball up (like mercury from a broken thermometer). In addition to shortening tip life, dewetting impairs heat transfer. The oxide build up acts as a thermal insulator. Frequently, the complaint that a soldering iron tip "isn't hot enough" is really a dewetting problem.

Iron oxidation occurs naturally during the soldering process. Flux is used to strip off oxide build-up on the tip and the leads to allow a solder joint to form. Because oxidation is a function of temperature and exposure to the oxygen in the air, the way to minimize oxidation is to keep the tip tinned (which covers the iron plating with a protective blanket of solder) and to solder at lower temperatures.

OKi and Metcal systems with SmartHeat® technology are designed to transfer heat more effectively at lower temperatures. Prolonged tip life is just one of the benefits of SmartHeat® technology, but the need for lower soldering temperatures has become particularly important with the use of lead-free soldering processes. For more information on the benefits of lower soldering temperature with OKi and Metcal systems, see the Technical Note, *High Throughput Soldering And Rework At Lower Temperatures With Smartheat® Technology*.

A thicker iron plating on the tip would not fix this problem, as it is the surface of the plating that oxidizes. The keys to preventing oxidation and dewetting are lower temperatures, regular tinning, and a suitably active flux.

The single most effective way to minimize oxidation and extend soldering iron tip life is simply to turn the system off when not in use. The rate of oxidation at room temperature is negligible compared to what it is at soldering temperatures. Turning the system off during breaks can result in an immediate 10-15% increase in tip life!

> **Note:** The heat-up time of a Metcal or OKi soldering tip cartridge is less than 30 seconds. Long heat-up times associated with conventional systems are a reason often given by operators for not turning their systems off.

Using the lowest possible temperature during soldering will reduce oxidation and extend tip life. There is a tendency to solder at higher temperatures than needed. Not only does this shorten tip life, it needlessly increases the risk of PCB damage. With Metcal and OKi systems, many customers have found that shifting to a lower temperature cartridge results in no loss in throughput and a significant increase in tip life.

Oxidation can also be controlled by limiting the exposure of the solder tip to air. The best way to do this is to keep the tip tinned when stored. This shields the iron plating from the oxygen in the air.

Dewetting can also occur if the flux being used is not active enough (or if no flux is used). This is typically the case with "No-Clean" solders. Currently, the most common tip plating failure associated with No-Clean solders is dewetting (see Appendix A, *About No-Clean Solders*). Tip dewetting while using No-Clean solders is not a problem caused by the soldering iron tip. It is a process problem involving the interaction between the tip, flux, solder, and temperature.

Dirty sponges are one further cause of dewetting. In addition to the corrosive by-products mentioned earlier, dirty sponges collect solder dross that contains heavy metals. This dross can adhere to the iron plating, forming a non-wetting surface. Hard water also contains elements which can form a bonded, non-wetting surface. To prevent this, use only clean sponges wet with deionized water.

Should a tip become detinned, it can be restored by use of a commercial tip tinner. These products contain an abrasive used to strip the oxide and can be used to squeeze out more life from a ruined tip. Unfortunately, this same abrasive will also remove some of the iron plating as well as any oxide, shortening tip life. Therefore, the best practice is not restoration, but prevention.

Wear/Abrasion Failures

Plating failure due to wear is the only unpreventable failure mode experienced by all soldering iron tips. In a sense, plating wear is the "proper" mode of failure for a tip. The other failure modes discussed are preventable with care. Normal wear is caused by the abrading away of the iron plating as the tip comes into contact with solder joints. A worn tip will typically show a hole on its working surface.

Wear life is affected by two things: plating thickness and operator practice. Plating thickness is limited by tip geometry and thermal responsiveness. Too thick a plating can limit thermal responsiveness. While this is less of an issue with conventional, stored energy type soldering irons which inherently have sluggish response times, it is an issue with Metcal and OKi systems, which rely more on speed of thermal response than stored energy to achieve good heat delivery control.

In addition, fine point and slim tips cannot carry as much iron plating as blunter tips without losing their sharp profiles. Tip life can often be extended simply by selecting a blunter over sharper tip wherever possible. Resist the common tendency to pick the finest tip. Often, the blunter tip is the right tip.

Wear can be minimized by not applying excessive force during soldering, and by not "scrubbing" the tip against the joint. As in the case of excessive force, operators often believe incorrectly that "scrubbing" aids heat transfer. It does not.

Drag soldering will cause tips to wear out faster. Drag soldering is equivalent to running a soldering iron tip across a metal file. Besides accelerated tip wear, drag soldering on through-hole leads is a questionable practice with respect to solder joint quality. Because the solder tip spends almost no time on the lead, the solder joint may have insufficient time at the proper temperature to form a strong bond (resulting in a weak, brittle, or cold joint).

For these reasons, OK International and Metcal developed the SMTC-0147 Multi-lead soldering tip. This tip is specially designed to handle the rigors of "drag" soldering, and is designed to ensure the proper joint.

Occasionally, commercial tip tinners are used during normal soldering operations for reasons of convenience. This should not be done. Commercial tip tinners are designed to restore detinned tips to working condition. They contain an abrasive, and are not meant to be used for routine tinning. The abrasive will cause excessive wear of the iron plating. For routine tinning, a flux core solder wire or flux bearing solder paste is recommended.

Finally, never use an abrasive material like sandpaper, emery cloth, rags, Scotch-Brite®, or dry sponges to clean a tip. Use a clean, wet sponge.

If there is a buildup on the tip, you may want to use a brass brush (AC-BRUSH) to clean the buildup.

Summary of Soldering Tip Cartridge Care Guidelines

The following lists summarize tip care issues and the recommended tip cartridge care practices. By making these care practices part of daily habit, you should be able to enjoy maximum tip life.

Cracking:

- Select the largest tip possible for the lead being soldered.
- Do not apply excessive pressure when soldering. To maximize heat transfer, tin the tip.
- Take care not to bang the solder tip against the metal workstand when inserting the tool.
- Do not use tips as a screwdriver or a prying tool.

Wear:

- Select the largest tip possible for the lead being soldered. Blunter tips carry more plating.
- Do not apply excessive pressure during soldering.
- Do not "scrub" the lead. To maximize heat transfer, tin the tip and create a solder bridge.
- Do not drag solder. If you must drag solder be aware that it will shorten tip life.
- Do not use commercial tip tinners for routine tinning. Use a flux core solder wire or paste.
- Use a clean, wet sponge to clean the tip. Do not use a dry sponge, rag, or any abrasive.

Corrosion:

- Select lower activity fluxes where possible. RMA flux is best for maximum tip life.
- Use only sulfur free sponges for cleaning tips.
- Use only clean sponges. Discard dirty sponges.
- Use RMA solder to tin tips during storage. Do not use aqueous or high activity flux solders.

Dewetting:

- Turn the system off when not in use.
- Use the lowest possible temperature when soldering. Low temperature reduces oxidation.
- Keep tips tinned when in use and during storage. This keeps air from the tip.
- Use a flux with suitable activity during soldering. Use only clean sponges. Use deionized water to wet the sponges.

No-Clean Solders:

- Use the lowest possible temperature. Low temperature reduces thermal oxidation, solvent volatilization, and polymerization.
- Periodically use an RMA wire solder or solder paste to tin the tip.

Heater Care:

- Do not use pliers to change tip cartridges. Use a Cartridge Removal Pad.
- Do not drop tip cartridges onto hard surfaces.
- For surface mount tips, do not bang the tips to dislodge components. Use a sponge.

Tip Cartridges and Heater Tips/Coil Assemblies

The OKi or Metcal tip cartridge is more than just a soldering tip. Unlike conventional tips which are simply plated copper forms, an OKi/Metcal tip cartridge is a complete soldering iron, so there are a few additional care practices specific to tip cartridges.

Note: This information also applies to the OKi heater tips and coil assemblies, such as the PS-CA1, PS-CA2, and MFR-CA1. For the purpose of this Technical Note, we will refer mainly to tip cartridges.

The OKi/Metcal tip cartridge (**Figure 5**) is comprised of a heater tip, coil, shaft and power connector. The heater is embedded in the tip and this heater tip assembly is pressed into the shaft. The coil slips over the heater and leads to the connector which plugs into the solder handle cord. The coil supplies electrical power to the heater. There are no separate thermocouples; the heater alloy itself is the temperature control mechanism. (For more details on how an OKi or Metcal tip cartridge functions, see the Technical Note, *SmartHeat® Technology*.)

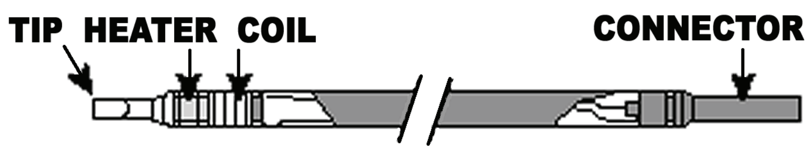


FIGURE 5: OKi & Metcal Tip Cartridge

This means that each time you replace the tip cartridge (or tip/coil assemby), you automatically install a new heater/coil assembly with the new tip. Because of this and the absence of any temperature control circuitry, the cartridge requires no calibration or special maintenance, unlike conventional soldering systems. Care for anOKi/Metcal tip cartridge, as well as for OKi tip/coil assemblies, consists for the most part of following the standard tip care practices detailed earlier and avoiding physical abuse to the cartridge.

Care of Heater/Coil Assemblies

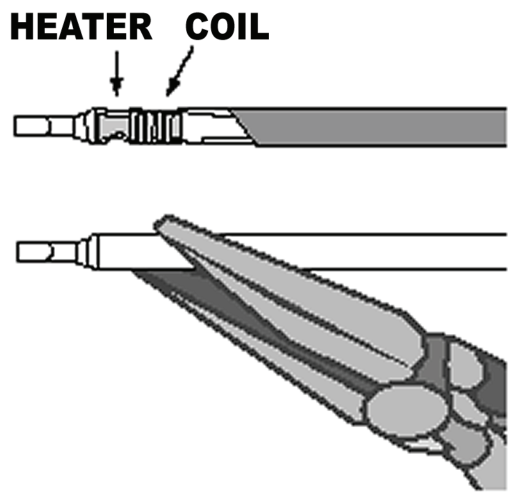
Due to the simplicity of construction, the heater/coil assembly in an OKi/Metcal tip cartridge is extremely robust. OKi/Metcal warrants its tip cartridge heater/coil assemblies for 200 hours and they are engineered to last well beyond this period. Under proper care, the heater/coil assembly should outlast the plating.

However, the heater/coil assembly can be damaged by abuse. The two most common forms are described below.

Heater Abuse #1: Using Pliers to Change Tip Cartridges

The most common abuse is using pliers to remove the cartridge from the handle. Pressure from the pliers deforms the shaft, damaging the heater/coil assembly (see **Figure 6**). Never use pliers to change a tip cartridge! Metcal supplies an insulated silicone rubber Cartridge Removal Pad (AC-CP2) with every system. Use only a Cartridge Removal Pad to change the tip cartridge.

Figure 6: Damage From Pliers



Heater Abuse #2: Mechanical Shock

The heater/coil assembly can also be damaged by severe mechanical shock. Dropping the cartridge onto a floor or benchtop can damage it. In the case of SMTC surface mount removal tips, damage can occur from banging the tip cartridge against a workstand or other hard surface to dislodge a surface mount component from the tip. Instead, to dislodge a component from the tip, either wipe it gently on the workstand sponge or use tweezers to separate the component from the tip.

Troubleshooting Heater Failures

OKi and Metcal systems consist of three major parts: the tip cartridge (or the tip/coil assembly), the solder handle/cord, and the power supply. Failure of the heater/coil assembly will show up as either a "no heat" or apparent low temperature condition. While it is most likely that a "no heat" or low temperature condition is caused by a failure of the heater/coil assembly, a problem in the solder handle/cord or the power supply could show up as a "no heat" condition.

Cartridge Does Not Heat

- Check that the power supply is plugged in and turned on. The "power on" LED should be lit.
- Check to make sure the solder handle/cord is tightly connected to the power supply and the cartridge is seated firmly in the handle/cord.

> **Note:** Note: if you have an enhanced power supply (identified by two LEDs) and the yellow LED is lit, you have a discontinuity in the electrical path. Refer to the Troubleshooting section of your owner's manual to determine the source of the discontinuity.

- If the cartridge still won't heat, try a new, known good cartridge. If the new cartridge heats, you have a cartridge heater/coil failure.
- If the new cartridge does not heat, the failure is somewhere else in the system. Refer to the Troubleshooting section of your owner's manual to determine the source of the failure.

Cartridge Seems Cool, Heats Intermittently, or Heats and Then Goes Cold

- Try a known good cartridge. If the known cartridge heats, you have a cartridge heater/coil failure in the new cartridge.
- If you have a Net Power Meter (NPM-50), plug it in. With the suspect cartridge inserted, tap the handle lightly with your finger. If the needle jumps erratically, you have an intermittent cartridge.
- A dewetted tip is often improperly diagnosed as a cold tip. This is because dewetting sometimes impairs heat transfer between the tip and solder joint. To check for dewetting, apply solder to the tip. If it balls up and does not flow across the tip, the tip is dewetted, and not a heater/coil failure.

Appendix A: About No-Clean Solders

The trend away from CFCs is leading many users to evaluate switching to No-Clean soldering processes. The term "No-Clean" is actually a common misnomer when used to describe a flux or solder. Technically speaking, No-Clean actually refers to a process, not a flux. So-called No-Clean fluxes should more accurately be termed "Low Solids" fluxes. However, for the purposes of this discussion, we will accept common usage; the term "No-Clean" solder will be used to refer to a solder that makes use of a low solids flux.

In evaluating a switch to a No-Clean process, users are generally aware that they may incur higher costs associated with reduced throughput, higher solder joint defect rates, and more stringent board handling practices. These are balanced against the savings of eliminating the capital equipment, solvent, and labor costs associated with the cleaning step. If the savings outweigh the added costs, adoption of a No-Clean process usually follows.

The bad news is that in addition to these costs, users should recognize right up front that tip costs will increase unless more rigorous tip care standards are enforced. The good news is that enforcing these standards through operator care and training does work.

Users first adopting the use of No-Clean solders in hand soldering often experience a decrease in soldering iron tip life. In virtually all known cases, dewetting is the failure mode associated with No-Clean solders. The reasons for these are quite complex. To understand them, it is first necessary to understand what it is about No-Clean solders that can lead to increased dewetting and shorter tip life.

No-Clean fluxes typically contain an alcohol solvent carrier with < 2% solids. The solids are primarily synthetic resin (although some have natural rosin) containing a halide-free activator system. The most common activator is adipic acid, although other acid activators are in use. Flux chemistry varies greatly according to manufacturer. Consult your flux, solder wire, or solder paste supplier for more details.

With respect to tip life, there are three factors common to most No-Clean solders that contribute to dewetting.

No-Clean Solders Tend To Be Less Active Than Traditional RMA Solders

At soldering temperatures, the iron plating of the tip is constantly oxidizing. If the flux is not active enough, it will strip the oxides at a slower rate than the oxidation buildup. In other words, it is like trying to shovel snow off a driveway during a snowstorm. As long as the snowfall is light, you can keep the driveway clear. As the rate of snowfall gets faster relative to the speed of shoveling, at some point you can't keep the driveway clear.

To solve this, it is necessary to either increase flux activity (shovel faster) or decrease the oxidation rate (slower snowfall). One way to decrease oxidation is to solder at lower temperatures, which becomes particularly important when addressing the higher thermal demands of lead-free soldering processes. The rate of oxidation is strongly dependent on temperature. In several cases, reducing the temperature by 100 degrees Fahrenheit has been enough to allow No-Clean solder flux to keep pace with the oxidation and eliminate dewetting.

Periodic tinning of the tip with a large diameter RMA flux core solder or solder paste during soldering can be used to strip off excess oxide buildup during soldering. At regular intervals during soldering with a No-Clean, tin the tip with an RMA solder, wipe it off on a clean, wet sponge, then continue soldering with the No-Clean solder.

No-Clean Solvent Carriers Are More Volatile Than In Traditional RMA Fluxes

Because of this, at traditional soldering temperatures, the flux solvent carrier volatilizes too quickly, carrying the flux away from the tip before it has a chance to strip the oxide.

Again, to solve this, solder at a lower temperature. This slows down the volatilization rate, giving the flux time to react and strip the oxide from the tip.

No-Clean Fluxes Commonly Use Synthetic Resins Instead of Natural Rosin

At high temperatures, there is some evidence that these synthetic resins and activators may be polymerizing, coating the soldering iron tip with a non-wetting, polymer film. This film appears as a blackish residue on the tip. This dewetting failure is different from the more common dewetting caused by thermal oxidation.

If this is occurring, solder at a lower temperature. This reduces the chance of the polymer film forming. Also, you can remove the polymer film (black residue) from the tip with a commercial tip tinner. There are also fiberglass brushes, tinning "blocks", and glass filled rubber eraser-type products that can be used to remove black residue from the tip without harming the iron plating. However, the permissible use of the brushes or erasers must be evaluated within the context of site-specific safety and cleanliness standards.

There is a third alternative put forth by some flux manufacturers: to use a No-Clean flux that makes use of natural rosin and not a synthetic resin. However, as the ability to do this varies from manufacturer to manufacturer, you should check with your flux supplier.

In general, a No-Clean hand soldering process is less robust than one using a more active flux, like RMA. This means the process is more sensitive to operator technique—or operator error. Hand soldering and tip care practices that were acceptable with RMA solders may not be effective with No-Cleans.