Solder Heat Bridge

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Background

It does not matter if you work in electronics, industrial metal joining, roofing or stained glass, all of these joining operations and their related cousins are striving for a "good solder joint." Most of us can cite that we want a good solder joint but fewer of us can actually define what makes a good solder joint. While entire books have been written on this subject we need only concern ourselves with meeting two conditions:

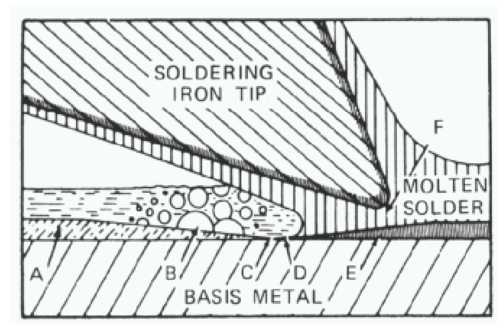
1. Provide a strong mechanical bond between the surfaces being joined.
2. Provide a proper electrical connection between the surface being joined.

A large population of soldering personnel might argue number two is not necessary to their soldering, but they are complementary and if you achieve one, you will achieve the other.

Solder Flow

When you make a solder connection, a number of things happen fairly quickly. Once the soldering iron has been applied to the surfaces being joined, heat flows into the connection. As the solder itself starts to heat, the flux will begin to melt and flow at around 150°F (65.5°C). As the heat continues to rise the flux starts to activate and boil off at around 180°F (82.2°C). The flux flows out over the connection, cleaning the surfaces and protecting them from oxidation as the heat continues to rise.

As the connection area continues to heat, the solder (in a Tin/Lead [SnPb] model) begins to soften at 361°F (182.7°C) and becomes molten at round 374 °F (190°C). While the solder is held in this molten state, new layers (intermetallics) form which serve to either strengthen or weaken the solder connection.



A. Flux solution lying above oxidized metal surface.
B. Boiling flux solution removing the film of oxide.
C. Bare metal in contact with flux.
D. Liquid solder replacing flux.
E. Tin [Sn] reacting with the Copper [Cu] forming the CuSn intermetallic.
F. Solder Heat Bridge

Note: Soldering iron tip shown not touching the basis metal for clarity.

Intermetallic layers†

Solder bonds or "wets" to metals in a process in which it is joined by a metallurgical reaction with the base metal. This is a totally different process than that which takes place when water wets a surface. This metallurgical bonding process results in the formation of an intermetallic compound layer between the solder and the base metal. For example, if a molten Sn-based solder is placed in contact with clean Cu, the metallurgical reaction between Sn and Cu will result in the formation of a layer of Cu_6Sn_5. This intermetallic layer is the 'glue' that holds the solder joint together … In the Sn-Cu system, a second intermetallic compound can form between the Cu and the Cu_6Sn_5 layer. This is Cu_3Sn which has quite different (non-solderable) properties than the Cu_6Sn_5 compound … it is usually advisable to keep the layers as thin as possible (generally between 1 and 2 micrometers) and protected from the atmosphere by a layer of solder … Intermetallic compounds can be found in two places in a solder joint. Preferably, they are in a thin continuous layer between the solder filler metal and the base metals.

Where's the Heat?

With all due apologies to the late Sara Peller of Burger King® hamburger fame, all solder connections boil down to the ability of the soldering technician to deliver BTUs (heat) to the area being joined. Generally speaking, this operation must be performed in a quick manner so that the "good" intermetallic (Cu_6Sn_5) compound can form and the workpiece allowed to cool back to room temperature. The longer the technician spends working the solder connection, the more likely that "bad" (Cu_3Sn) intermetallic compound will start to form between the good intermetallic and copper of the connection surface.

The properties of Cu_3Sn are such that in electrical work the resulting electrical junction will be of a higher resistance. This can generate excess heat within the solder joint and degraded performance of today's high speed electrical circuits. In the mechanical model (which also includes the electrical circuits) the Cu_3Sn interface is quite brittle and subject to fracture and other mechanical failures.

The use of a Solder Heat Bridge allows for the quick and expeditious transfer of BTU's (heat) into the connection so that solder connection can be efficiently completed and cooled.

The Solder Heat Bridge

The Solder Heat Bridge is nothing more that the small amount of molten solder that is situated between the face of the soldering iron tip and the material being soldered. It acts as a conduit by which BTU's may be rapidly transferred from the soldering tip to the workpiece. [See item "F" in the above illustration.]

In most soldering operations the sequence of soldering will be as follows:

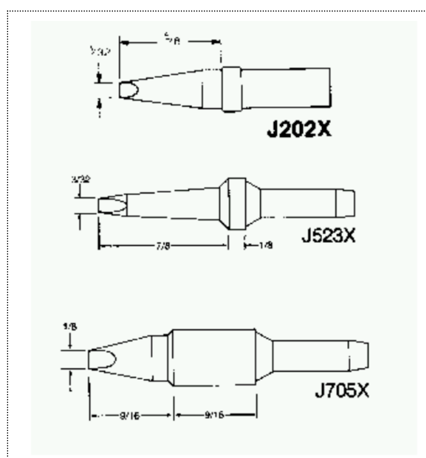
1. Ensure the workpiece is properly positioned and clean.
2. Apply flux as necessary.
3. Remove the soldering iron from its holder and wipe the tip on a wet cleaning sponge.
4. Tin the soldering iron tip by applying a light, thin coat of solder to the tip.
   Note: If the tip is in good condition the solder will evenly coat the tip and the surface will be smooth and bright. If the solder wants to ball instead of coating the tip, then the tip is not ready for the soldering operation and must either be cleaned or replaced before continuing.
5. Hold the solder so that it is positioned at the point where the iron will be applied to the material to be soldered.
   Note: This will normally be at the point where the metal pieces meet.
6. Place the tinned tip into the solder, which should immediately melt and form the Solder Heat Bridge.
7. Move the solder to the opposite side of the connection. As the area being joined heats, the solder will start to melt and will then flow toward the heat source. Add solder as necessary to maintain the volume of solder needed to complete the connection.
8. Remove the soldering iron and solder, being careful not to disturb the connection while it cools.
9. Clean the tip on the sponge, retin with a thick coating of solder, and return the soldering iron to its holder.
10. If necessary, clean the workpiece once it has cooled an the solder has solidified.

In most light duty situations, such as those found in electronics soldering, steps 5 through 8 should take 2 to 5-seconds to complete. In sheet metal work these steps might take a considerably longer time, but the operational principles remain the same. In either case, it is the Solder Heat Bridge which makes it happen in the most efficient manner.

When the Solder Heat Bridge is not present a number of negative factors can come into play, all of which will serve to make the completion of the connection more difficult and lengthy.

The Soldering Iron

Every soldering iron manufacturer specifies irons in their own unique manner and a way that presents their equipment in the best possible light. While some of the supporting features the manufacturer adds to their equipment may be key to supporting the iron's operation, we are interested in only two features in terms of making the good solder connection. These are 1) Thermal Mass and 2) Wattage.



The thermal mass is nothing more than the reservoir of BTU's that the iron has stored away and available to make the connection. A good example of this is the Hexacon Therm-O-Trac soldering station. In its most basic configuration it is outfitted with a J202X 3/32" Semi-Chisel tip. By merely swapping the case assembly are replacing the tip with either a J523X or J705X tip, you can get a proportionally higher tip mass while maintaining the same basic tip style and shape. When making a solder connection with this solder station, or any soldering iron, it is the available heat energy stored in this tip mass that will be used to make the solder connection.

Assuming that the thermal load of the workpiece is sufficient to deplete the available heat energy stored within the tip, you must then rely on the heater (watts) to both replenish the tip, as well as provide any additional BTU's to complete the connection. The wattage of the iron needs to be carefully selected.

Too low a wattage and the iron will not be able to keep up with the demands of the tip mass and the work load. Too high a wattage and you may dump energy into the connection at such a rate that you may end up with a poor quality solder connection.

If the soldering iron has been properly selected, then the Solder Heat Bridge will allow it to deliver optimal performance. This is why a Hexacon Phenix soldering iron, costing under $100, with its variable power control circuitry can frequently out perform soldering stations costing $800 and more.

Summary

The Solder Heat Bridge is nothing more that the small amount of molten solder that is situated between the face of the soldering iron tip and the material being soldered. It provides the conduit by which heat can be rapidly and efficiently transferred from the soldering iron tip to the solder connection. Failure to achieve a proper Solder Heat Bridge will likely lead to a defective solder connection that may not have apparent visual signs pointing to its poor quality.

[†] Task Group 5-22f, *IPC-HDBK-001*, 3/1998 ed., s.v. "Hand Book and Guide to the Requirements for Soldered Electrical and Electronic Assemblies to Supplement ANSI/J-STD-001," 21, 22.