Application Note

Guidelines for Hand-Assembled Splicing of Amperium® Wire

Amperium wire contains a YBCO ceramic thick film deposited on an oxide-buffered Ni-W alloy substrate. The YBCO film is coated with silver and laminated on both sides with a metal foil (copper, brass, or stainless steel) utilizing solder having a 179° C melting point. The basic construction is illustrated in Figure 1.

Amperium wire can be easily spliced together with very low resistance joints that will have virtually no impact on overall superconductor performance. The purpose of this Application Note is to provide guidance on how to splice Amperium wire in the field using two different types of joints. Before proceeding and attempting to splice Amperium wire, please review Application Note Guidelines for Termination of Amperium Wire (http://www.amsc.com/library) for more information on general handling and soldering issues.

The electrical resistance of soldered connections to Amperium wire depends on several factors including solder material, surface cleanliness, contact uniformity, and joint length. Another important factor is the side of the wire used to make contact. The construction of Amperium wire is asymmetrical and the side closest to the YBCO layer provides a lower resistance path to the superconductor core. Contacts made to the opposite side will have higher resistance due to the substrate. To easily distinguish the two sides in the field, the higher resistance side of the wire is marked as "Substrate Side" (see Figure 1).

There are two basic methods for splicing Amperium wires: overlap joints and strap splices. Details on the assembly methods and performance for each type are provided in this document.

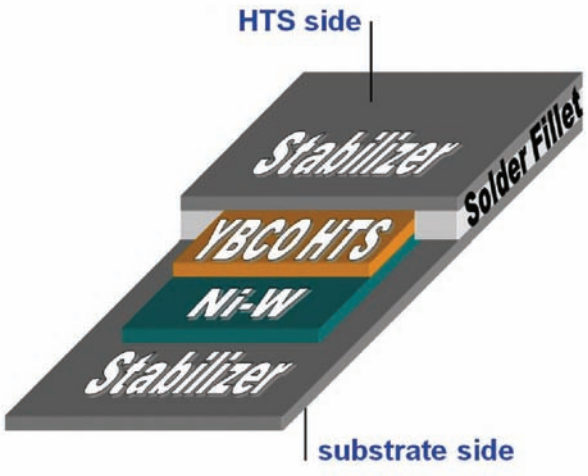

Figure 1. Structure of Amperium wire

General Guidelines for Soldering

- The surface to be soldered must be smooth, clean, and free from any contamination.
- A non-corrosive solder flux (see recommendations in Table 1) must be applied prior to soldering. Do not immerse the wire in flux – use a brush or pen applicator.
- A low temperature solder with a melting temperature.

of less than 175 °C should be used. See Table 2 for two reccomended solders.

- The HTS wire must be heated to the recommended temperature in a well-controlled manner. To safeguard against possible delamination of the wire structure, Amperium® wire should not be exposed to temperatures exceeding the recommendations listed in Table 3. Always use the shortest times and lowest temperatures possible. In no case should the wire be exposed to temperatures exceeding 175 °C (347 °F).
- Gently contact the wire with the soldering iron until solder flows on the wire surface. Do not apply excessive pressure on the wire with the soldering iron tip.
- After assembly, clean the solder joint to remove any excess solder or flux residue.

Flux	Activation	Comments
Alpha 260HF Cookson Electronics www.alphametals.com	Organic acid	Halide-free, water based, water soluble
135 Kester,Inc. www.kester.com	Non-activated rosin	Solvent-based

Table 1. Recommended solder fluxes

Solder/Mfr	Description	Composition	Melt Point	Recommended Tip Temperature
Indalloy 1E Indium Corp. of America www.indium.com	Lower temperature, higher strength	52%In-48%Sn Eutectic	118° C (244° F)	135° C – 140° C (275° F – 284° F)
Indalloy 4 Indium Corp. of America www.indium.com	Higher temperature, lower strength	100% In	157° C (315° F)	170° C – 175° C (338° F – 347° F)

Table 2. Time and temperature guidelines for soldering to Amperium wire

Temperature Range	Maximum Time
165 °C – 175 °C (329 °F – 347 °F)	3 minutes
155 °C – 165 °C (311 °F – 329 °F)	20 minutes
145 °C – 155 °C (293 °F – 311 °F)	60 minutes

Table 3. Time and temperature guidelines for soldering to Amperium wire

Tools/Materials Required

- Suitable solvent for cleaning (methanol, ethanol, etc.)
- Lint-free cloth or tissue wipes
- Non-corrosive flux (Table 1)
- Low temperature solder (Table 2)
- Diagonal wire cutters (e.g., Knipex, Model 7491250 or Excelta, Model 7142E)
- Temperature-controlled soldering iron with chisel tip (e.g., Weller, Model WD1M / WP80)
- Solder tip thermometer (e.g., American Hakko Products, Model FG-100)
- A small wooden dowel or "orange stick" to apply pressure on the joint during assembly
- A heat tolerant (low thermal conductance) work surface, such as a G-10 phenolic sheet
- A straight edge, such as a 30 cm long steel rule, to assist with alignment

Overlap Joints

A simple overlap joint can be used to join two Amperium wires with minimal electrical resistance. This configuration typically joins the HTS sides of two wires to produce the lowest resistance joint. Figure 2 illustrates the basic construction of this type of splice. (In applications that require maintaining the HTS orientation across the joint, a substrate side to HTS side splice can used, but the electrical resistance will be significantly higher). The recommended length for a splice of this type is between 25 mm and 100 mm. As a guide to the electrical performance that can be expected of this type of joint, Table 1 lists some typical resistance values of overlap splices on Amperium wires.

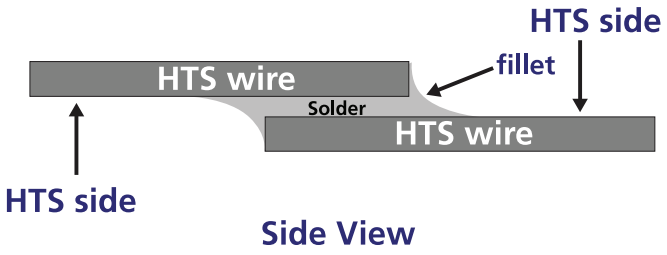

Figure 2. Overlap splice joint construction

Amperium Wire Type	Overlap Splice Joint Length (mm)	Resistance* (nano-ohms)
Copper Laminated	25	80
	50	40
	100	20
Brass Laminated	25	260
	50	130
	100	65
Stainless Steel Laminated	25	1400
	50	700
	100	350

*not a guarantee of performance

Table 4. Typical resistance values of overlap splice joints for 4.4 to 4.8mm wide Amperium wire types

Overlap Splice Joint Assembly

1. Wire Cutting

a. Cut clean, straight ends on the wires using the recommended tool. All ends should be free from burrs and sharp protrusions.

2. Wire Preparation

a. Wipe all surfaces to be soldered with a solvent-soaked cloth.

b. Apply flux to the low resistance or HTS side of the first wire.

c. With the soldering iron set to the appropriate temperature, "tin" the fluxed portion of the wire with a thin coating of solder over the desired length as shown below in Figure 3.

d. Repeat steps b) and c) for the second wire.

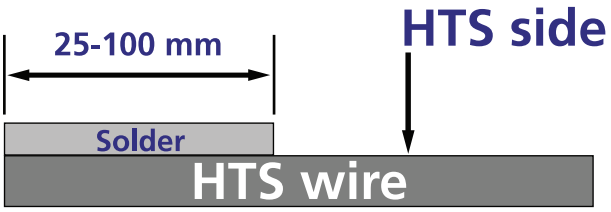

Figure 3. Tinned wire for overlap joint

3. Soldered Joint Assembly

a. Wipe the tinned surfaces of both wires clean with a solvent-soaked cloth.

b. Apply flux over both tinned surfaces.

c. Flip one of the wires over and position the HTS wires together with the correct overlap of the tinned surfaces as shown below in Figure 4.

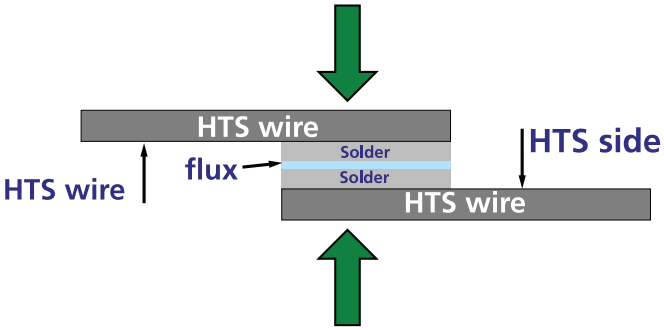

Figure 4. Overlap joint preassembly

d. Roughly align the wires along their lengths and secure them in position. An example of how to do this is shown in Figure 5. Here, the wires are taped to a heat-tolerant work surface such as a G-10 phenolic plate. Note that the adhesive tape must be far enough away from the solder joint to avoid exposure to temperatures that will damage or burn the tape.

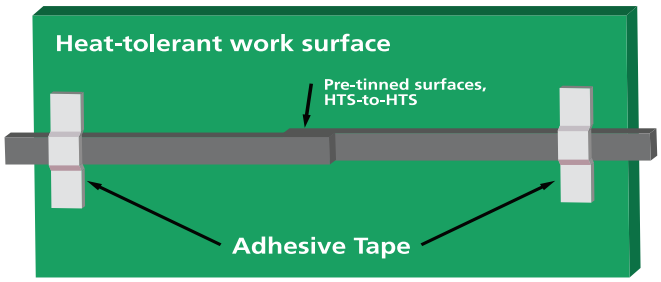

Figure 5. Method of positioning and securing HTS wires for soldering of overlap joint

e. Ensure good axial alignment of the two wires by checking the two pieces against the straight edge.

f. Use the soldering iron to apply heat to the outer surface of the top wire until solder reflow occurs at the joint. Work the joint from one end to the other by slowly moving the solder tip along the length of the overlapped wires.

g. Apply gentle pressure to the joint with the orange stick and remove the soldering iron. Maintain slight pressure until the solder has solidified.

h. Ensure that each of the wire ends are filleted by solder (as shown in Figure 2) to help prevent separation during bending operations.

4. Finishing/Rework

a. Remove any excess flux with solvent.

b. If excess solder must be removed, genlty use an Xacto® knife or similar sharp instrument to trim the solder.

Strap Splices Composed of Two Overlap Joints

The second type of field joint for Amperium® wire is a double overlap joint or strap splice, as shown in Figure 6. This geometry maintains the HTS orientation in the joined wires by utilizing a short piece of wire to bridge the two wire lengths at the joint. The strap wire is simply a short section of the same type of wire being joined and is soldered with its low resistance side contacting the low-resistance sides of the two longer lengths (i.e., HTS-to-HTS orientation for all joints). For the best mechanical performance, it is recommended that the gap between the two wires beneath the strap be at least 10 cm. As a guide for expected electrical performance, typical resistance values of a variety of symmetrical, 10 cm gap strap splices are provided below in Table 5.

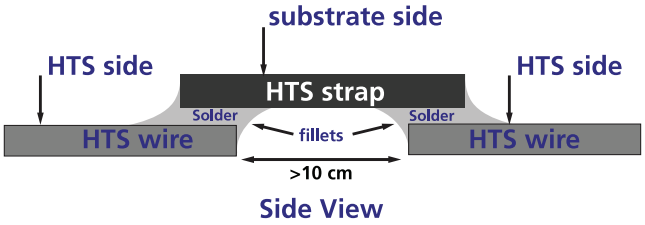

Figure 6. Strap Splice Construction

Amperium® Wire Type	Total Splice (Strap) Length With 10 cm gap (mm)	Total Splice Resistance* (nano-ohms)
Copper Laminated	25	160
	50	80
	100	40
Brass Laminated	25	520
	50	260
	100	130
Stainless Steel Laminated	25	2800
	50	1400
	100	700

*not a guarantee of performance

Table 5. Typical resistance values of 10 cm gap strap splices for Amperium wire

Strap Splice Assembly

1. Wire Cutting

a. Cut clean, straight ends on the wires and the strap wire using the recommended tool. All ends should be free from burrs or sharp protrusions.

2. Wire Preparation

a. Wipe all surfaces to be soldered with a solvent-soaked cloth.

b. Apply flux to the low resistance or HTS side of each wire.

c. With the soldering iron set to the appropriate temperature, "tin" the fluxed portion of the wires with a thin coating of solder as shown below in Figure 7.

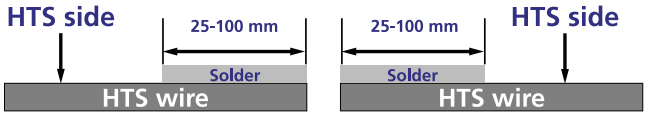

Figure 7. Tinned wires for strap splice overlap joints

d. Repeat above steps for the strap wire, applying a thin layer of solder over the ends of the HTS strap that will form the two joints, as shown below in Figure 8.

Figure 8. Tinned strap wire

3. Soldered Joint Assembly

a. Wipe all surfaces to be soldered with a solvent-soaked cloth

b. Apply flux to both tinned surfaces.

c. Position the two wires together with the tinned surfaces facing up and desired gap between them. Place the strap wire on top of the two wires so that it bridges the gap as shown below in Figure 9.

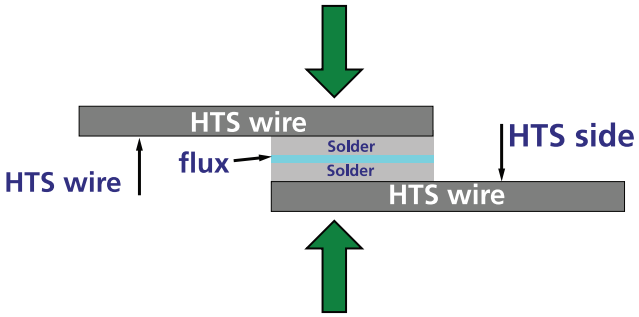

Figure 9. Strap splice preassembly

d. Roughly align the wires along their lengths and secure them in position. An example of how to do this is shown in Figure 10. Here, the wires are taped to a G-10 phenolic plate which provides a good heat-tolerant work surface. Note that the adhesive tape must be far enough away from the solder joint to avoid exposing it to excessive heat.

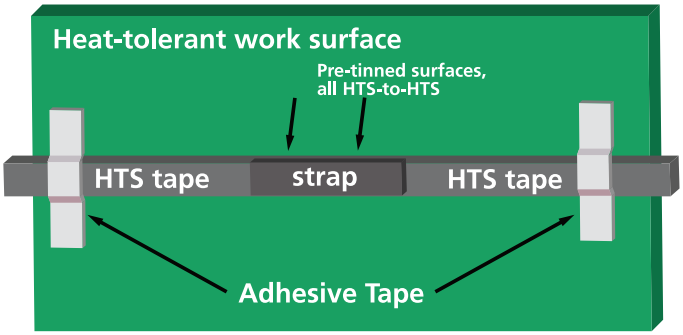

Figure 10. Method of positioning and securing HTS wires for soldering of strap splice overlap joints

e. Ensure good axial alignment of the two wires by checking the two wire pieces against the straight edge.

f. Starting with either one of the joints, use the soldering iron to apply heat to the outer surface of the strap wire until solder reflow occurs at the joint. Work the joint from one end to the other by slowly moving the solder tip along the length of overlapped wires.

g. Apply gentle pressure to the first joint with the orange stick and remove the soldering iron.

h. Repeat Steps f) and g) for the second joint.

i. Ensure that end of each of the tape ends is filleted by solder (as shown in Figure 6) to help prevent separation during bending operations.

4. Finishing/Rework

a. Remove any excess flux with solvent.

b. If excess solder must be removed gently, use an Xacto® knife or similar sharp instrument to trim the solder.

www.amsc.com

smarter, cleaner
... better energy