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Service Note SN003
Guidelines for Hand-Assembled Splicing of 344 Superconductors

Introduction

344 superconductors contain 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.

344 superconductors can be easily spliced together with very low resistance joints that will have virtually no impact on overall superconductor performance. The purpose of this Service Note is to provide guidance on how to splice 344 superconductors in the field using two different types of joints. Before proceeding and attempting to splice 344 superconductors, please review Service Note SN002-0109 (http://www.amsc.com/products/htswire/index.cfm) for more information on general handling and soldering issues.

The electrical resistance of soldered connections to 344 superconductors 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 344 superconductors 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).

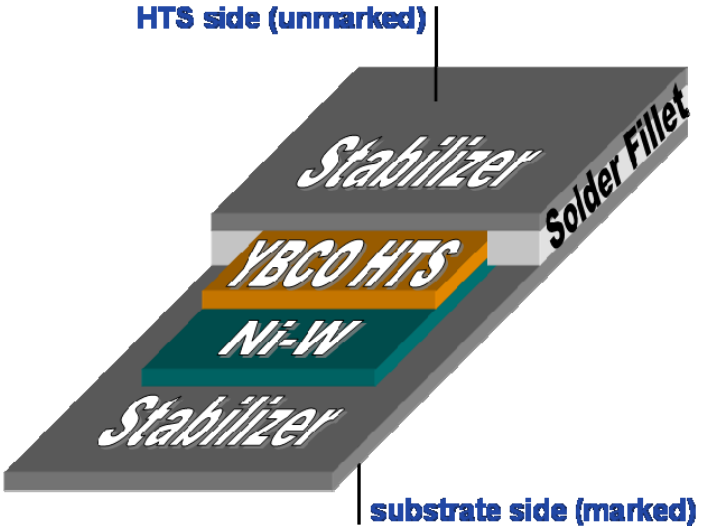

Figure 1. Structure of 344 Superconductors

There are two basic methods for splicing 2G HTS wires; overlap joints and strap splices. Details on the assembly methods and performance for each type are provided below.

Overlap Joints

A simple overlap joint can be used to join two 2G 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 344 superconductors.

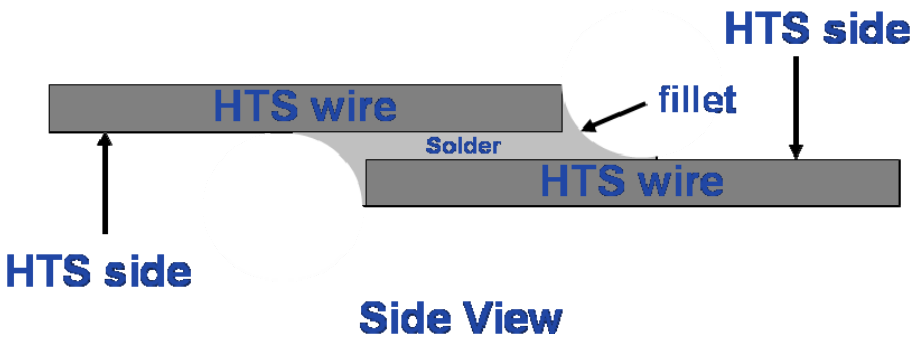

Figure 2. Overlap Splice Joint Construction

Table 1. Typical Resistance Values of Overlap Splice Joints for Type 344 Superconductors

2G Wire Type	Overlap Splice Joint Length (mm)	Resistance* (nano-ohms)
344C	25	80
	50	40
	100	20
344B	25	260
	50	130
	100	65
344S	25	1400
	50	700
	100	350

*not a guarantee of performance

Tools/Materials Required:

- Suitable solvent for cleaning (methanol, ethanol, etc.)
- Lint-free cloth or tissue wipes
- Non-corrosive flux (see http://www.amsc.com/products/htswire/index.cfm)
- Solder (see http://www.amsc.com/products/htswire/index.cfm)
- Diagonal wire cutters (recommended tool: Knipex Model No. 7491250)
- Temperature-controlled soldering iron with a spade or chisel tip
- A small wooden dowel or “orange stick” to apply pressure on the joint during assembly
- A heat tolerant work surface, such as a G-10 phenolic plate
- A straight edge, such as a 30 cm long steel rule, to assist with alignment

Overlap Splice Joint Assembly:

1. Wire Cutting

a. Cut clean, straight ends on the HTS 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 HTS 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.

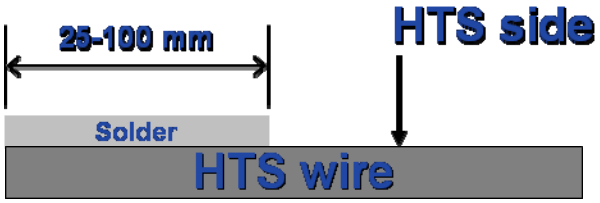

Figure 3. Tinned Wire for Overlap Joint

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

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.

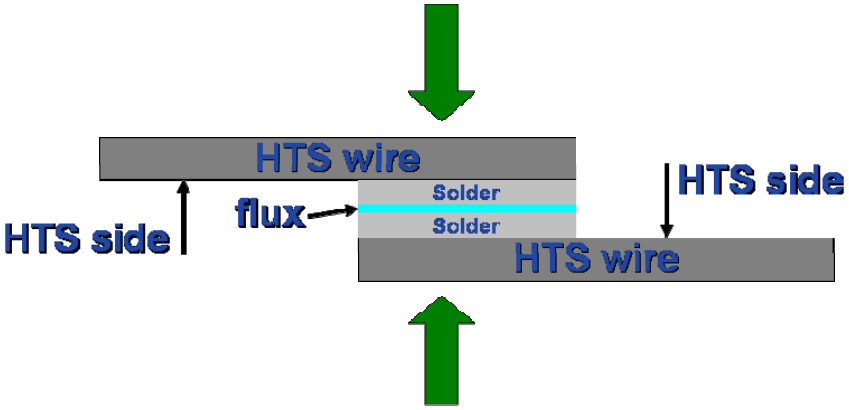

Figure 4. Overlap Joint Preassembly

   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 HTS 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.

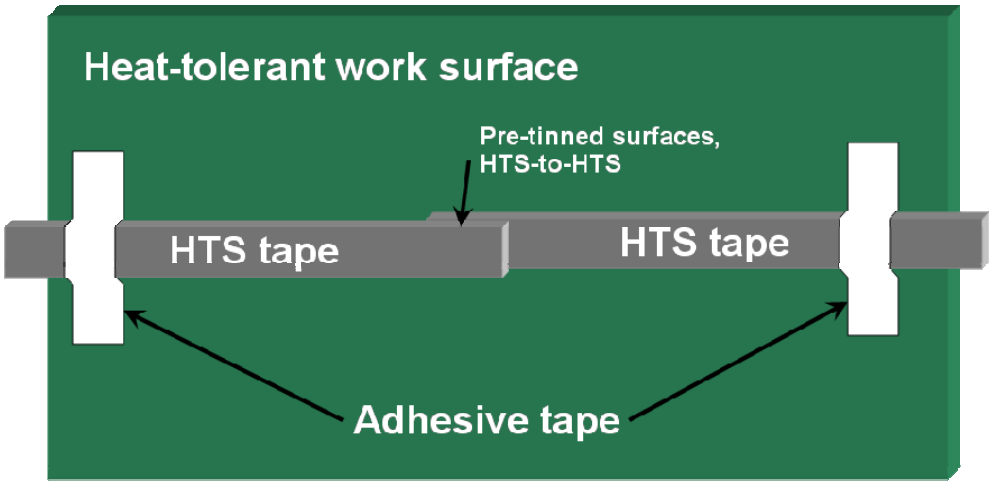

Figure 5. Method of Positioning and Securing HTS Wires for Soldering of Overlap Joint

e. Ensure good axial alignment of the two HTS 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 at 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 HTS tape ends is 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, 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 2G superconductor tapes 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 2.

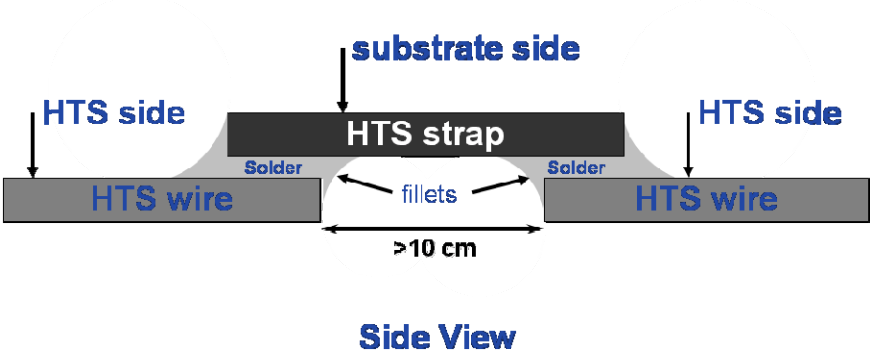

Figure 6. Strap Splice Construction

Table 2. Typical Resistance Values of 10 cm Gap Strap Splices for Type 344 Superconductors

2G Wire Type	Total Splice (Strap) Length With 10 cm gap (mm)	Total Splice Resistance* (nano-ohms)
344C	25	160
	50	80
	100	40
344B	25	520
	50	260
	100	130
344S	25	2800
	50	1400
	100	700

*not a guarantee of performance

Tools/Materials Required
See lap joint section above.

Strap Splice Assembly:

1. Wire Cutting
   a) Cut clean, straight ends on the HTS 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.

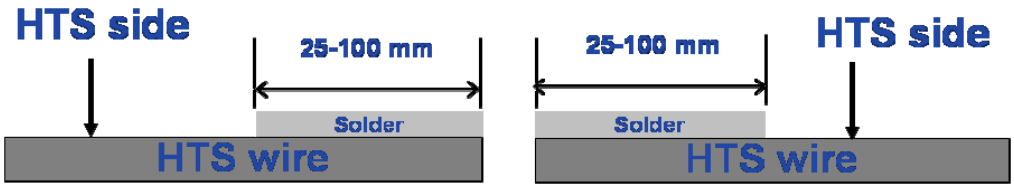

Figure 7. Tinned wires for Strap Splice Overlap Joints

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 HTS 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.

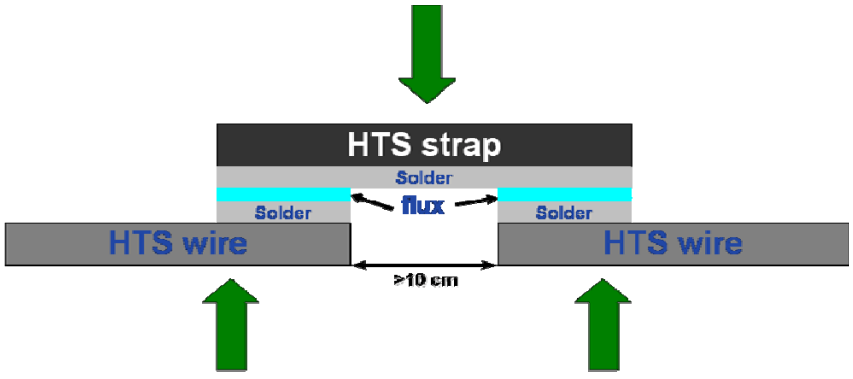

Figure 9. Strap Splice Preassembly

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 HTS 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.

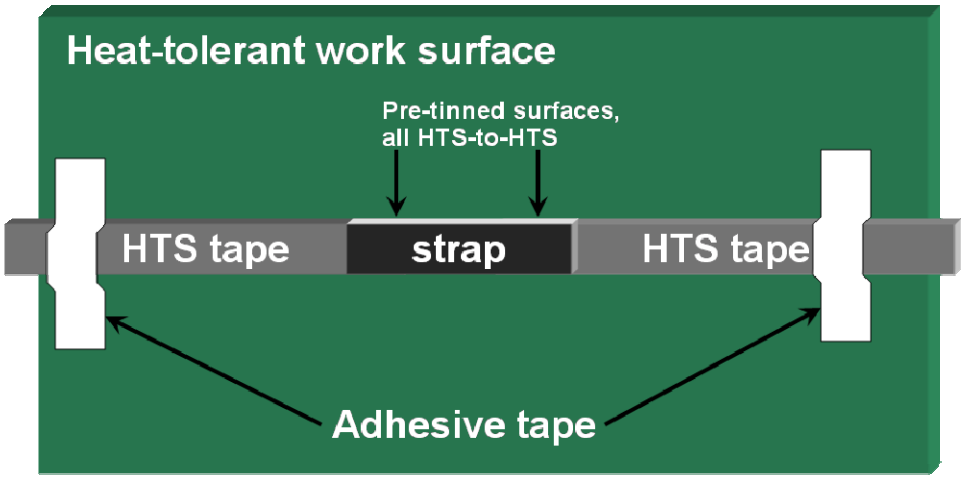

Figure 10. Method of Positioning and Securing HTS Wires for Soldering of Strap Splice Overlap Joints

e) Ensure good axial alignment of the two HTS 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 at 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, use an Xacto® knife or similar sharp instrument to trim the solder.

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