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## Procedure

# Splicing of MQXF short coils

### *Abstract*

This paper deals with the sequence of operations that have to be performed for the splicing of the coils of MQXF.

After the winding, curing and heat treatment, the coil is completed, and at one end the cable is coming out from the end spacers, to be connected with the power supply.

For this purpose, the Nb<sub>3</sub>Sn superconductive cable has to be elongated, using a NbTi wire and a copper stabilizer, soldered on it.

The procedure goes through the pre-tinning of the Nb<sub>3</sub>Sn cable, the cut and the splicing.

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History of Changes

Rev. No.	Date	Pages	Description of Changes
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**1. NECESSARY MATERIALS**

1	N°2 cables NbTi: <ul style="list-style-type: none"><li>• Width 18.15 mm</li><li>• Thickness 1.92 mm</li><li>• Length 1500 mm</li></ul>	
2	N°2 copper stabilizers	
3	Soldering alloy: Sn <sub>96</sub> Ag <sub>4</sub> , strips with dimensions 20x0.2 mm and coil of wire with diameter 1.0 mm	
4	Flux: MOB39	
5	Brush	
6	N°1 Thermocouple, capable to reach 250°C	
7	N°2 Heating cartridges with power control system, capable to reach 250°C	
8	Compressed air supply	
10	Aspirator to aspire smokes produced during the soldering.	
11	White Alcohol and Acetone	

12	White cloths	
13	G11 fillers. See paragraph 0.	
14	<ul style="list-style-type: none"> <li>• Dremel cutting tool</li> <li>• abrasive disk for stainless steel</li> </ul>	
15	<p>Clamps of two types like the ones shown in the figure:</p> <ul style="list-style-type: none"> <li>• to close the mould</li> <li>• to keep together the cable and the stabilizer</li> </ul>	
16	Electrical heater, like the one shown in the figure	
17	<p>Tools according to the following drawings:</p> <ul style="list-style-type: none"> <li>• Dwg LHCMQXFT0193, last revision: SQXF – Tinning sequence</li> <li>• Dwg LHCMQXFT0194, last</li> </ul>	

revision: SQXF – Cutting  
sequence

- Dwg LHCMQXFT0195, last  
revision: SQXF – Cable  
cleaning sequence
- Dwg LHCMQXFT0197, last  
revision: SQXF – Splicing  
sequence

## **2. PREPARATION AND CLEANING**

After the reaction heat treatment, the upper part of the mould has been dismantled and the shims and insulation layers have been removed from the outer layer of the coil.

So the coil will appear like in the following figure.

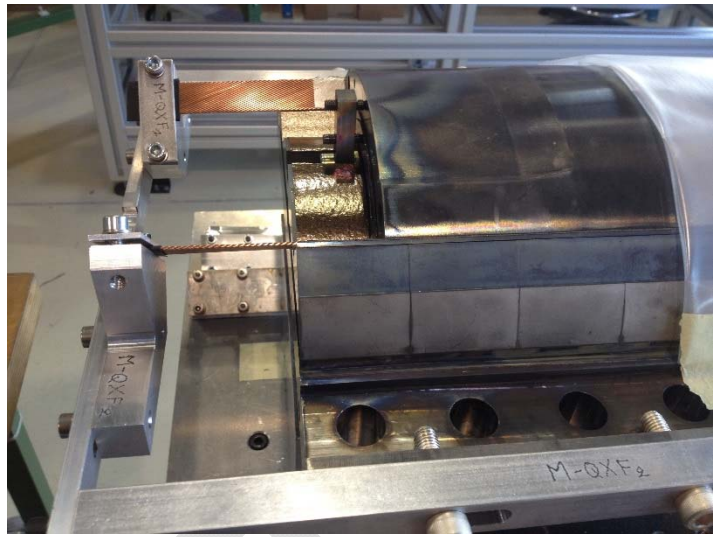


This paragraph goes through the operations to be performed for the removal of the splice blocks and the cleaning of the cable.

1

Take care that the support of the cable is installed on the mould.

If not, install it.



2

- Remove the splice blocks and the Mica insulation between them.
- Remove the lateral shims and insulation.

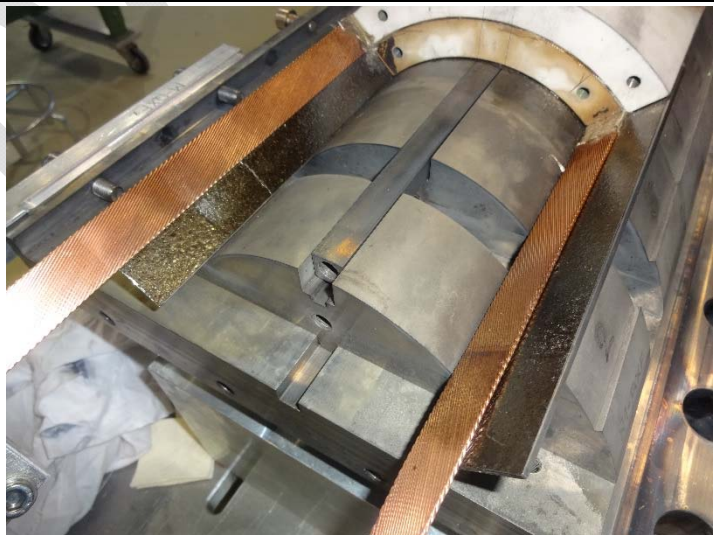
The situation that you will get is shown in the figure.



3

Remove the first two sectors that fit on the inner layer of the coil.

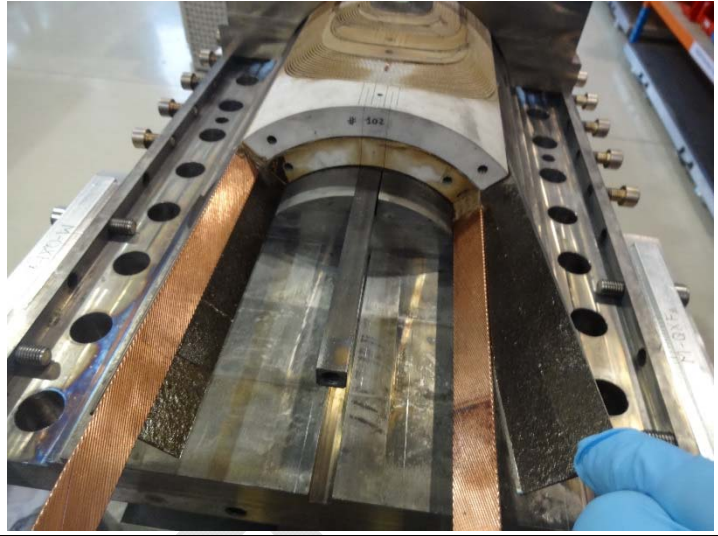
The removal shall be done by making them slide along the baseplate of the mould.





4

Remove the lateral Mica insulation and the midplane shim.



5

Remove the third sector of the mould.



6

The lead end will appear like this.





7

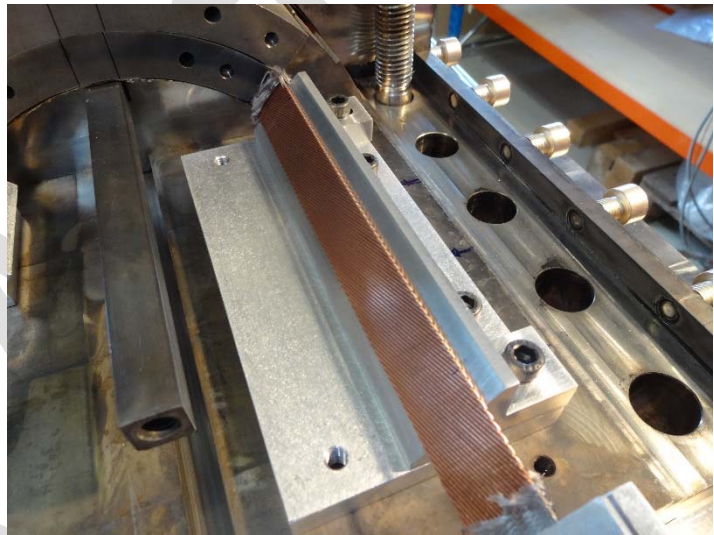
Assemble the upper part of the cleaning tool and clean the cable, using Acetone and white cloth.

NOTE: the figure shows the cleaning with foam rubber. However, it is better to do it with white cloth.



8

Assemble the lower part of the cleaning tool.



9

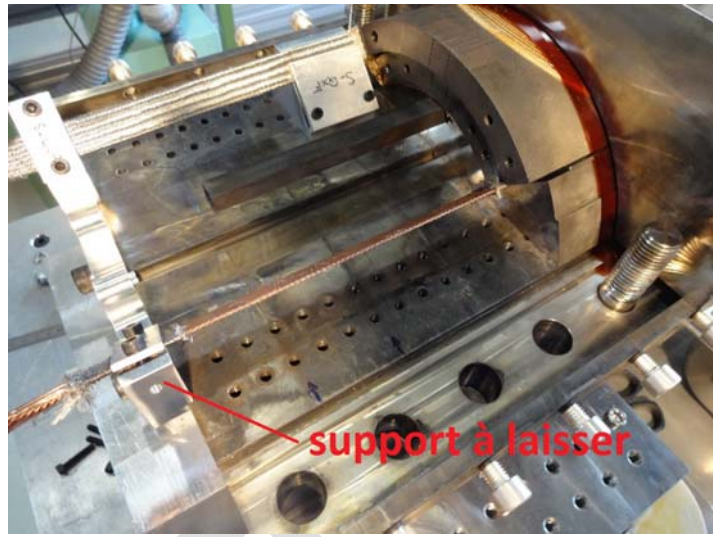
Clean the cable, using Acetone and white cloth.

NOTE: the figure shows the cleaning with foam rubber. However, it is better to do it with white cloth.



10

Dismount the cleaning tool, but leave the part connected to the end of the baseplate, to keep the cable.



### **3. PRE-TINNING OF THE CABLE**

The next operation to be performed is the pre-tinning of the cable. It is described in this paragraph.

1

Assemble the lower part of the tinning tool (dwg. LHCMQXFT0193).

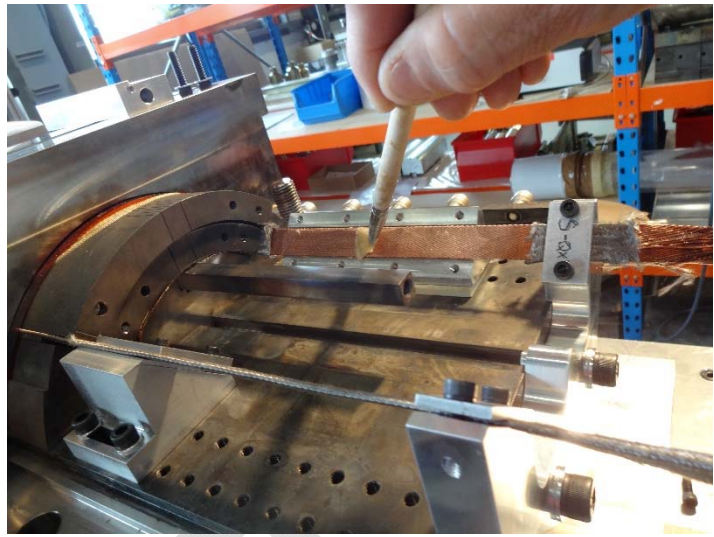
Remember to clean the mould (acetone and white cloth) before installation.





2

Apply the flux paste (MOB39) on the upper surface of the cable.



3

Clean the upper part of the mould with Acetone and white cloth.

NOTE: the figure shows the cleaning with foam rubber. However, it is better to do it with white cloth.



4

Apply the flux paste on the internal surface of the upper mould.



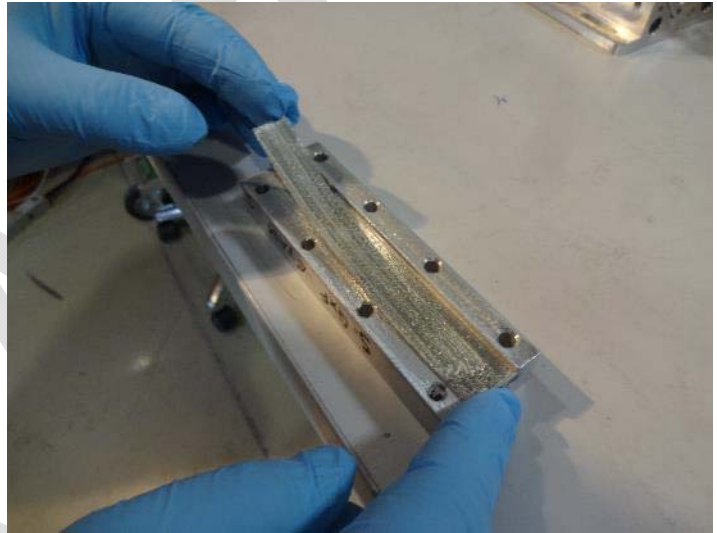
5

Prepare the strip(s) of soldering alloy (Sn96Ag4). One or more, in order to cover all the surface of the cable (depending on the width of the strips). Apply the flux on both surfaces of each soldering strip.



6

Place the strip(s) alloy on the mould.



7

Close the mould on the cable.





8

Place the heat cartridges and the thermocouple inside the proper holes.



9

- Set the temperature on the control unit at 240°C.
- Heat up the mould until 240°C;
- Leave the system at the constant temperature of 240°C for two minutes;
- Set the control unit back to 20°C.



10

When the temperature read from the thermocouple is 160°C, dismount the mould.

NOTE: Don't wait until room temperature is reached to open the mould, otherwise it would be difficult, since the assembly will stick.

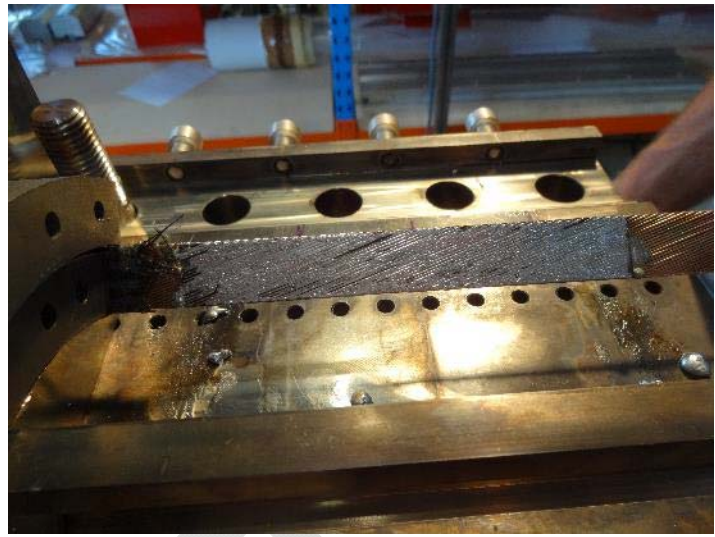
NOTE: after the reaction, the cable is brittle and easy to break. It is better to be two people performing this operation. Take a lot of care during this operation.





11

The cable is now pre-tinned.



12

When the cable is at room temperature, assemble again the mould around it, just for protection against bending.



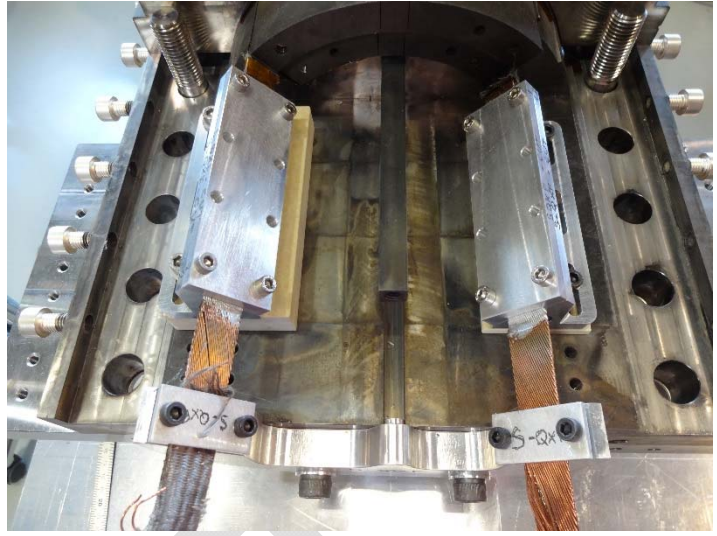
13

Clean the cable and remove the oxides from the surface:

- Scotchbrite and acetone (very lightly)
- Acohol and white cloth

14


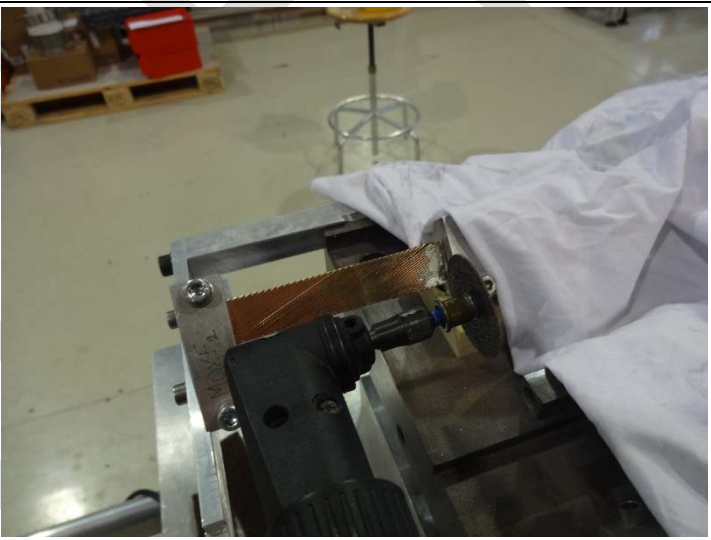
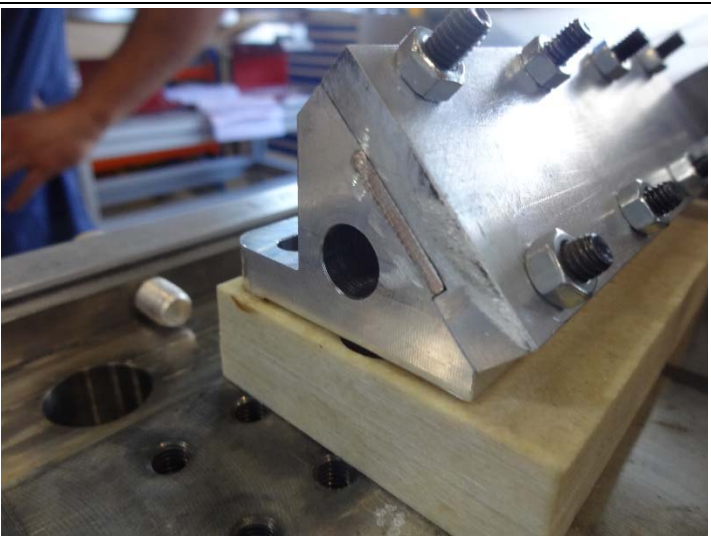
Repeat all the previous operation for the other lead.



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#### 4. CUT OF THE CABLE

The operation to be performed after the pre-tinning is the cut of the cable.  
The following steps show how to perform the operation.

1	<ul style="list-style-type: none"><li>• Assemble the long tool for keeping the cable, that is connected to the lateral side of baseplate of the reaction mould.</li><li>• Assemble the tool for cutting (dwg. LHCMQXFT0194)</li><li>• Put a cloth on the surrounding components to protect them from debris that can be produced during the cut</li></ul>	
2	<p>Cut the cable using the Dremel with abrasive disc.</p> <p>An abrasive disc for stainless steel is fine.</p> <p>Set the speed of the tool at the maximum.</p>	
3	<p>Remove the part of the cable that has been cut.</p>	

**4**

Replace the cutting tool with the support of the cable.



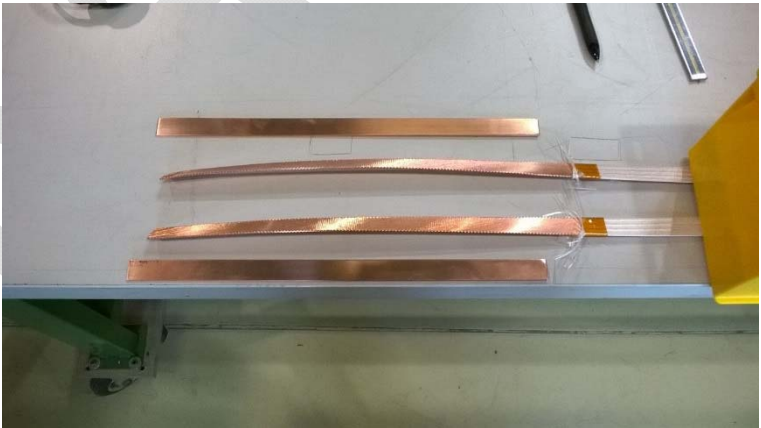


## 5. PREPARATION OF THE SPLICE

After the pre-tinning of the Nb<sub>3</sub>Sn cable, it is necessary to prepare the splices. The splices are made by a superconducting cable of NbTi and a copper stabilizer. The splices can be prepared in advance on the bench, and then they will be soldered to the leads of the Nb<sub>3</sub>Sn coming out from the coil.

It is necessary to prepare **n°2 splices**, to be soldered to the Nb<sub>3</sub>Sn cables of inner layer and outer layer.

The operations to be performed to solder the NbTi wire and the copper stabilizer are listed here in after.

1	Cut n°2 cables of NbTi <ul style="list-style-type: none"> <li>• Width 18.15 mm</li> <li>• Thickness 1.92 mm</li> <li>• Length 1500 mm</li> </ul>	
2	Cut n°2 copper stabilizer and machine it according to the drawing.  Perform the annealing heat treatment on the copper stabilizer (due to the responsible of heat treatments).  Perform the machining of the ends of the stabilizers (due to the responsible of the machining workshop).	
3	Clean the NbTi cables with scotch brite (very lightly)  Clean the copper strips and the NbTi wire, with acetone and white cloth.	
4	Clean the soldering Aluminum mould with acetone and white cloth.	

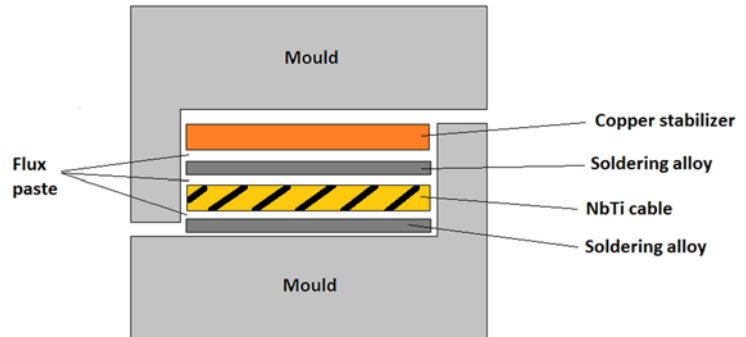


5

In the figure, a sketch of the layout of the component to be soldered is shown.

Always remember to put the flux paste between the surfaces to be soldered together.

The lowest foil of soldering alloy is placed now to pre-solder the surface of the NbTi cable before the following soldering with the Nb<sub>3</sub>Sn cable of the coil.



6

- a. Put one or more strips of soldering alloy on one half of the Al mould, to cover all the surface, depending on the size of the strip used.
- b. Apply the flux paste on the strip using a brush.



7

Put the cable on top of the alloy strip



8

- a. Put the flux paste on the top of the cable using a brush
- b. Put the other alloy strip on the top of the cable
- c. Put the flux paste on the top of the strip
- d. Put the copper stabilizer



9

Close the mould, press it with the clamps and put the screws to keep aligned the two halves.



Use an additional clamp to keep aligned the cable and the copper strip on the other side.



10

Place the heat cartridges and the thermocouple in the proper holes inside the mould.



11	<p>Place the aspirator on the top of the mould, to suck the smoke produced during the soldering.</p>	
12	<p>Set the temperature on the control unit at 240°C.</p> <ul style="list-style-type: none"><li>• Heat up the mould until 240°C;</li><li>• Leave the system at the constant temperature of 240°C for two minutes;</li><li>• Set the control unit back to 20°C.</li></ul>	
13	<p>Cool the mould using compressed air down to about 160°C.</p> <p>When the temperature indicated by the thermocouple is about 160°C, dismount the mould.</p> <p>NOTE: Don't wait until room temperature is reached to open the mould, otherwise it would be difficult, since the assembly will stick.</p>	



**14**

Now the soldering between NbTi cable and copper strip is complete for half of the length. In order to complete the connection between the two components, repeat the previous steps for the remaining length.

**15**

At the end of the soldering, remove the traces of oxidation from the splice in the following way:

- Scotchbrite and acetone (very lightly)
- Acohol and white cloth



## 6. SPLICING

After the completion of the soldering between NbTi cable and copper strip on the bench, go back to the coil.

The coil will appear like in the following figure, placed on its mould and with the cables supported by proper block after the cut already performed.



The splices (NbTi cable + copper stabilizer) have to be soldered to the Nb<sub>3</sub>Sn cables of the coil.

The following steps describe how to perform the splicing on the coil, i.e. the connection between the Nb<sub>3</sub>Sn superconducting cable and the NbTi cable.

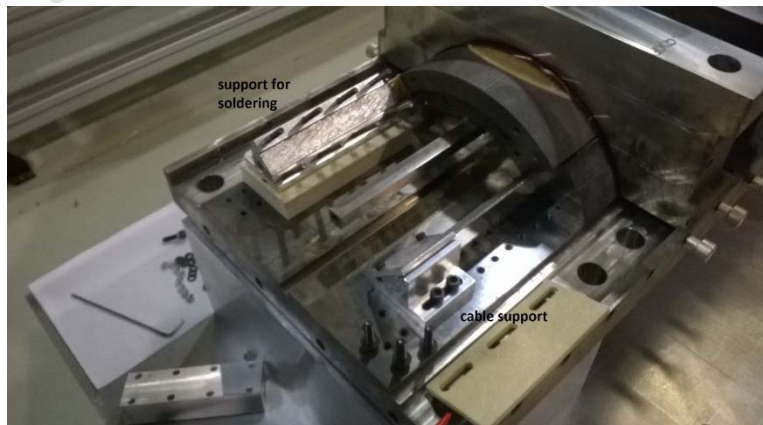
The same instructions are valid both for cable coming out from inner layer and cable coming out from outer layer.

1


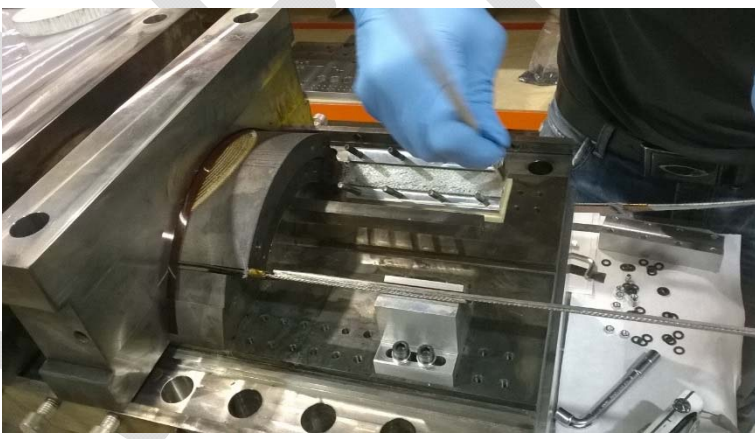

Dismount the support of the cable and replace it with the support for soldering (see dwg. LHCMQXFT0197).

Before placing the soldering support:

- Clean the cable with white cloth and acetone.
- Clean the mould with white cloth and acetone



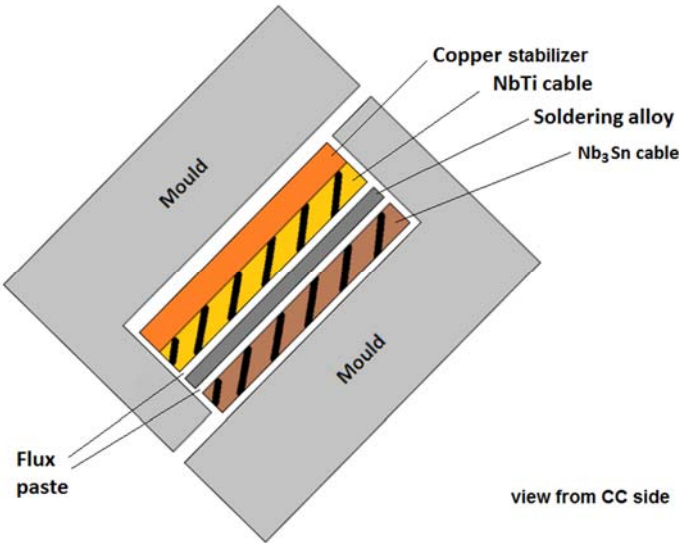


2	<p>Clean the components previously soldered on the bench (copper stabilizer + NbTi cable) with Acetone and white cloth.</p>	
3	<p>Adjust the position of the soldering block with respect to the spacer OC4. The distance between the spacer and the support shall be 18 mm.</p> <p>NOTE: the soldering supports for both cables (outer layer and inner layer) shall be put in the correct position with respect to the spacer OC4 of the outer layer.</p>	
4	<p>Apply the flux paste with the brush on the Nb<sub>3</sub>Sn cable.</p> <p>Only on the side where the splice is installed.</p>	
5	<p>Place the foil of soldering alloy on the cable.</p> <p>Apply the flux paste on the foil with the brush.</p>	

6

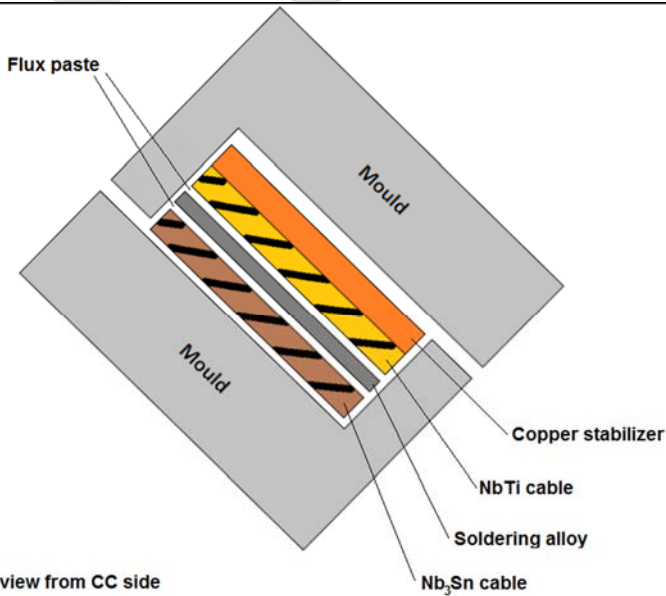
Place the NbTi cable with the copper plate, paying attention that the NbTi cable is on the side on the Nb<sub>3</sub>Sn cable.

The layout of the components for Inner Layer shall be as shown in the figure.



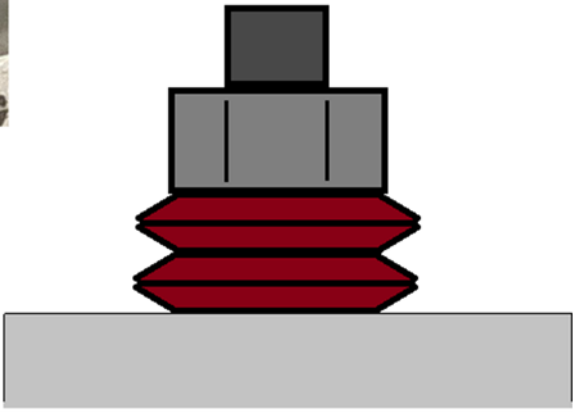
7

This figure shows the layout of the components to be soldered for Outer Layer.



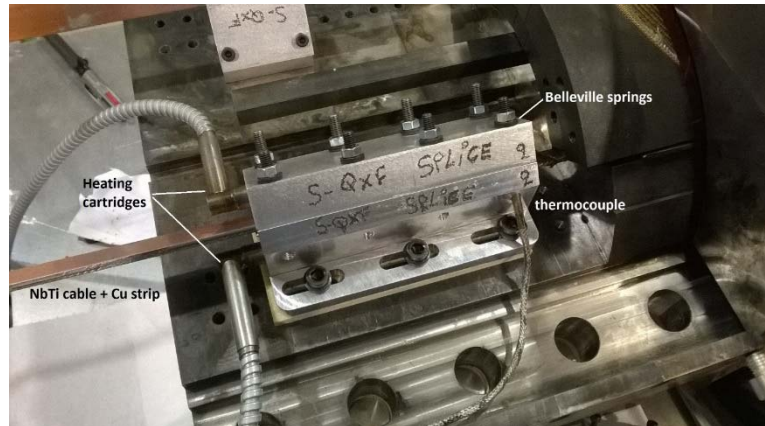
8

Close the mould with screws. Place the Belleville springs below the screws, as shown in the figure.



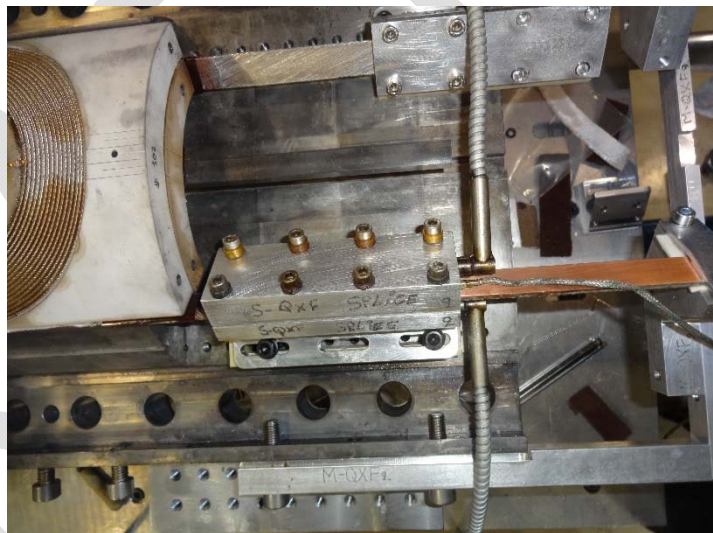
9

Place the heating cartridges and the thermocouple inside the holes in the mould.



10

- Set the temperature on the control system at 240°C and wait for the heating.
- When the alloy starts melting, tighten the screws a little bit.
- When the temperature goes to 240°C, wait for 2 minutes.
- Then, set it back to room temperature on the control system.



11

During cool down, start dismantling the mould when the temperature indicated by the thermocouple is about 160°C.

NOTE: during this operation, take care that the Nb<sub>3</sub>Sn cable coming out from the coil is not bent, since it is brittle and easy to damage. Ask help to another colleague if necessary.





**12**

Solder the vtap to the cable.  
It is worth to perform this operation just after the splicing, when the cable is still hot.

The VTAP shall be placed at about 6 mm from the end spacers, on the top of the cable.

NOTE: Take care that the Vtap is connected only to the Nb<sub>3</sub>Sn cable, and not to the NbTi cable / Cu strip

**13**

Take care of the orientation of the vtaps:

- Both of them are placed on the upper part of the Nb<sub>3</sub>Sn cables.
- The vtap of outer layer is oriented towards the outside of the coil
- The vtap of inner layer is oriented towards the inside of the coil

**14**

The soldering of the VTAP shall be done with an electrical heater, like the one shown in figure.

The alloy to be used is always Sn96Ag4, while the flux is MOB39.



15

At the end of the soldering, remove the traces of oxidation from the splice in the following way:

- Scotchbrite and acetone (very lightly)
- Acohol and white cloth

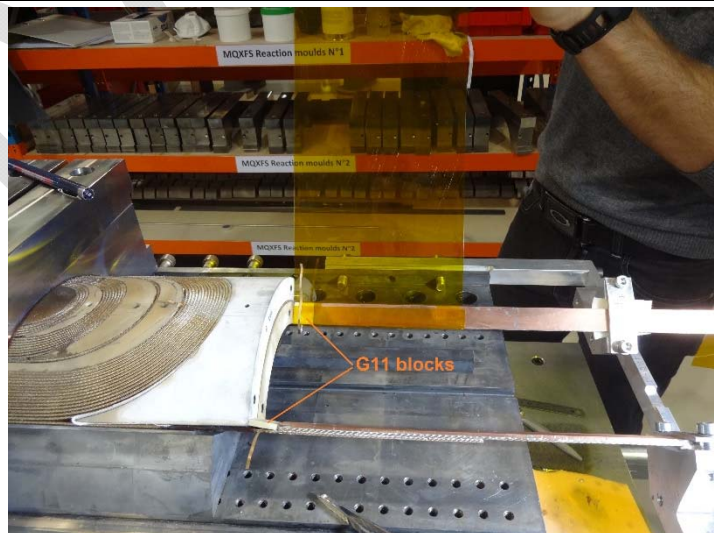
16

Install the long support for the cable.



17

Place two filler of G11, one on each vtap. The dimensions are such to fill the space between each splice and the end spacers of the coil





18

Place the kapton insulation all around the splice, including also the G11 filler.

- N°2 turn of kapton foil thk. 0.075 mm, total thickness 0.15 mm, on three side of the splice.
- Thickness 0.3 mm on the fourth side (between splice and splice block)

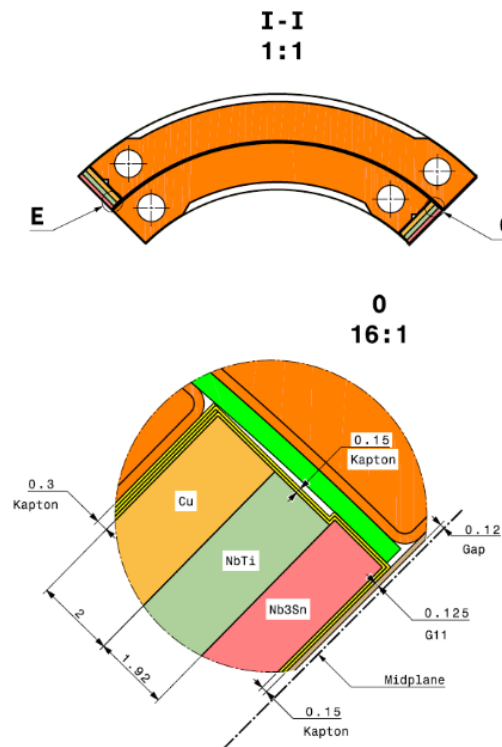
See also dwg. LHCMQXFT0163 and LHCMQXFM0156.

See also next point for more details.



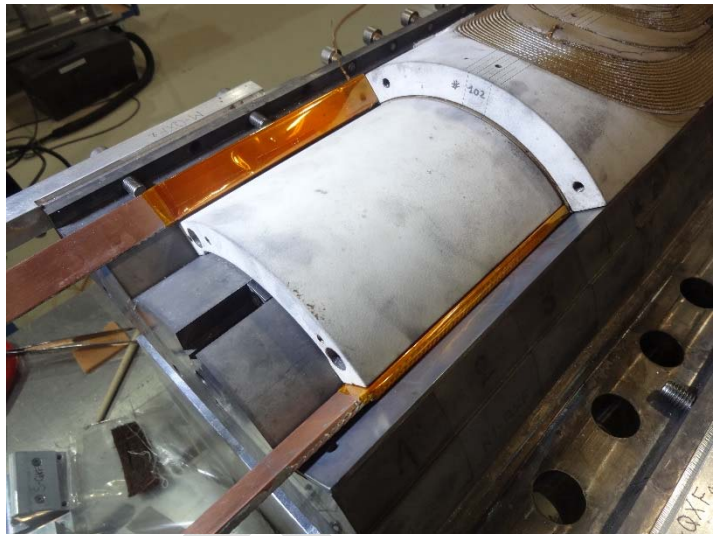
19

Detail of the thickness of the kapton insulation around the splice.



20

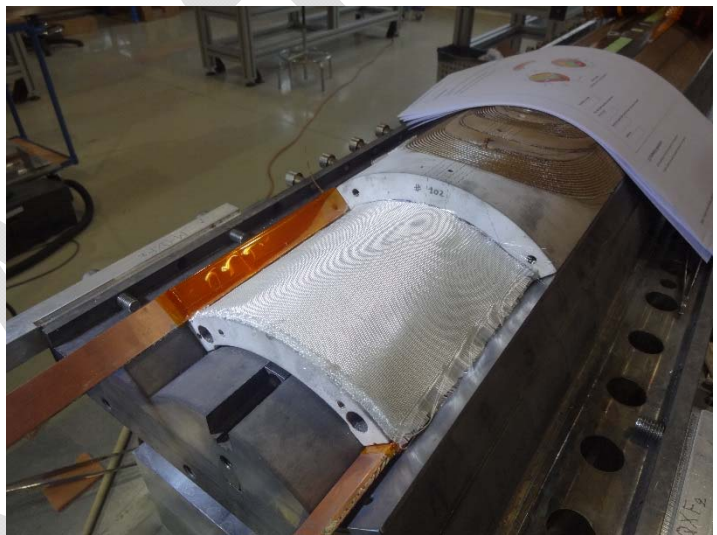
Install the sectors of the reaction mould to support the splice blocks and install the splice block of inner layer.



21

Place the interlayer insulation on the upper surface of the splice block of the inner layer: 0.5 mm S2 Glass.

See also dwg. LHCMQXFT0163.



22

Place the splice block of outer layer.

