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FRESCA 2 DIPOLE

Preparatory tests for winding to reaction

ESAC Revue | Maria Durante

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PREPARATORY ACTIVITIES

Different preparatory activities have been foreseen before starting first Nb3Sn coil winding :

- Winding tests to define end geometry
- Upside down winding
- Dishing measurements
- RMC manufacturing → Juan Carlos presentation
- Copper dummy coil manufacturing → Françoise presentation
- Ten stack tests
- Dilatation tests
  - Preliminary dilatation tests in U- shape
  - Dilatation tests in coil configuration

TEN STACKS TESTS

Goals :

Determine the dimensions under compression of the cable and of the cable insulation. Characterize winding mechanical behavior

Nb_3Sn cable nominal dimensions

- Width : 20.9 mm
- Thickness : 1.82 mm (measured during cabling process, under 50 MPa)
- Twist pitch: 120 mm
- Insulation thickness : 0.2 mm

Expected dimensions after reaction

- Width : 20.9 mm x 2% = 21.32 mm → 21.8 with insulation
- Thickness : 1.82 mm x 4 % = 1.893 mm → 2.3 mm with insulation

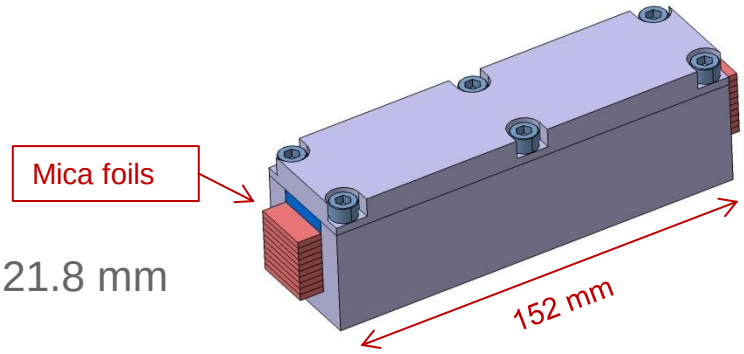
Ten stacks geometry

- Width : 21.8 mm
- Height : 23.0 mm
- Compressed length : 120 mm = twist pitch length

TEN STACKS MOLDS

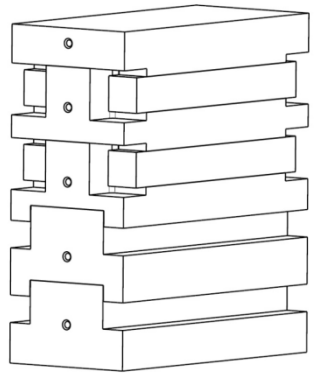
Reaction tools

- 4 reaction molds have been realized
- Reaction mold length : 152 mm
- Reaction Cavity width : 22 mm – 2 x 0.1 mica foils → 21.8 mm
- Cavity height : 28.4 mm + wedges



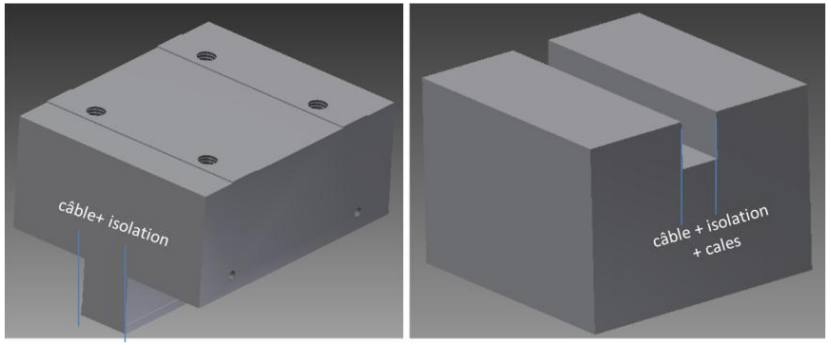
Impregnation tools

- Impregnation mold exist at Saclay
- An impregnation insert has been realized to fit the needed dimensions. Ten stacks are impregnated at the fixed height over a length of 140 mm
- Impregnation resin (Araldite MY750 + jeffamine D400) available at CERN



Compression mold

- Compression mold has been realized at CERN
- Mold cavity width: 24.2 mm
- Mold compression bar width: 24 mm



TEN STACKS TESTS PROGRAM

STACK	INSULATION	REACTION/CAVITY OVERTHICKNESS	IMPREGNATION	TEST	GOAL
ExNNN1	No	No	No	RT compression cycles → thickness of the non reacted bare cable	→ Non reacted cable thickness → Non reacted insulation thickness
ExINN1	Yes	-	No	RT compression cycles → thickness of an insulated non reacted cable	
ExNTN1	No	Yes / 26.5%	No	RT compression cycles → thickness of a bare cable when it is free to expand	Optimal reaction cavity x% for X cable
ExNTN2	No	Yes/ x%	No	RT compression cycles → bare cable thickness verification	
ExITN1	Yes	Yes/ x%	no	RT compression cycles→ thickness of an insulated reacted cable	→ Reacted insulation thickness
ExITI1	Yes	Yes/ x%	Yes	RT compression cycles + Thermal shrinkage	Impregnated cable mechanical behavior
ExITI2	Yes	Yes/ x%	Yes	4k compression cycles	
ExRITI3	Yes	Yes/ x%	Yes	RT compression cycles Thermal shrinkage	
ExITI4	Yes	Yes/ x%	Yes	RT compression cycles Thermal shrinkage	

- X = R for RRP cable and P for PIT cable. Tests have to be repeated on both type of cables.
- The first two non reacted samples of each type are available. Two “free cavity” ten stacks (ERNNN1 and EPNNN1) have been reacted. Room temperature compression tests could be carried out in March.

DILATATION TESTS

Goals :

Measure the dimensional changes along the cable length during reaction.

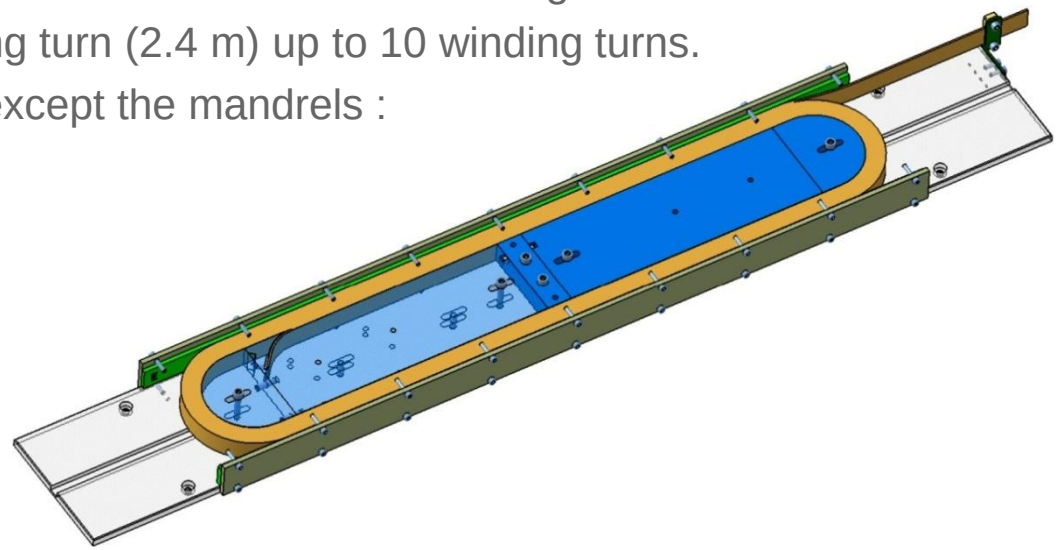
Investigate the impact of mandrel material on cable behaviour and the solutions to manage coil deformations

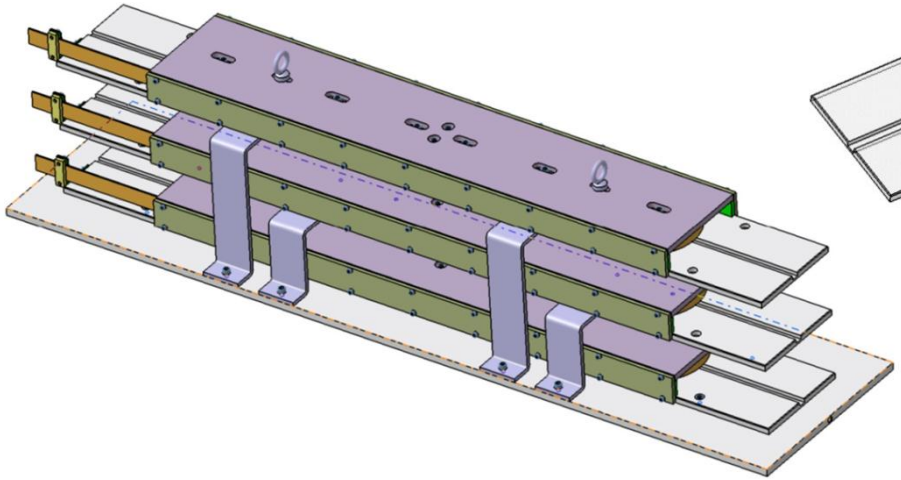
New fixtures has been realized to allow to wind the cable in a coil configuration.

The fixture is designed to fit form 1 winding turn (2.4 m) up to 10 winding turns.

All the fixture parts are in stainless steel except the mandrels :

- stainless steel, iron → Coil 1-2
- titanium → Coil 3-4



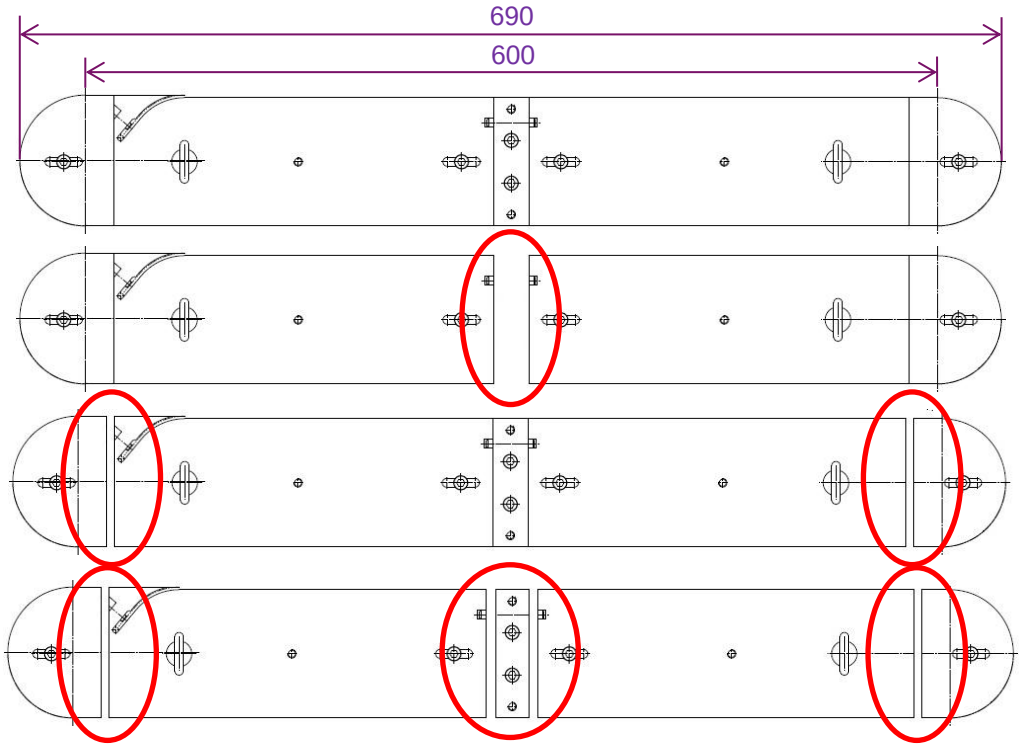


DILATATION TESTS TOOL

- Mandrel total length : 690 mm
- Straight section length: 600 mm
- Mandrel width: 90 mm
- 1.5 turns = about 2.4 m of conductor

Mandrel configurations

- Configuration 0, no gap
- Configuration 1 : central gap
- Configuration 2 : end gaps
- Configuration 3 : end and central gaps



TEST CAMPAIGN ON PIT CABLE AND RRP CABLE

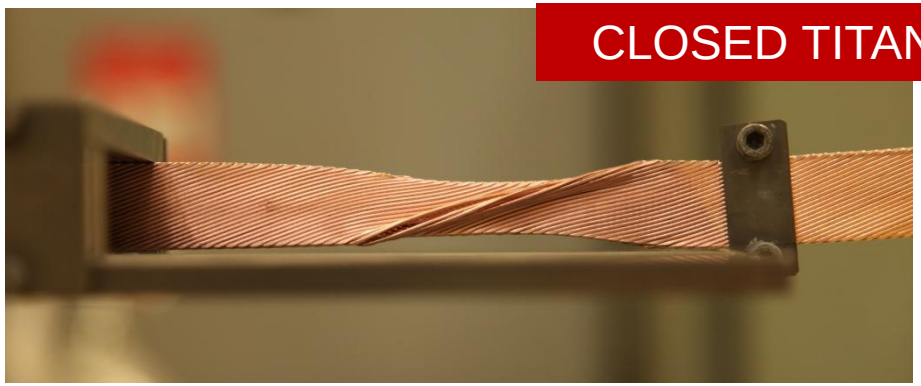
- Four heat treatments have been carried out up to now on PIT cable.
- Only one test on RRP cable

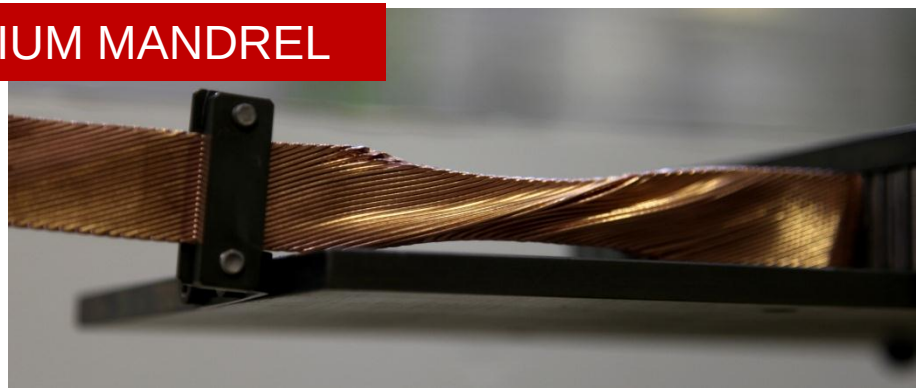
PIT CABLE	Configurations			
Mandrel material	**C0 – no gap**	**C1 - one central gap**	**C2 - 2 head gaps**	**C1bis - one head gap**
Iron	-	HT1	HT2 and HT3	HT4
Titane	HT1	HT2	HT3	HT4
Stainless Steel	HT1	HT2	HT3	-

RRP CABLE	Configurations			
Mandrel material	**C0 – no gap**	**C1 - one central gap**	**C2 - 2 head gaps**	**C1bis - one head gap**
Iron	-	-	-	-
Titane	-	HT5	-	-

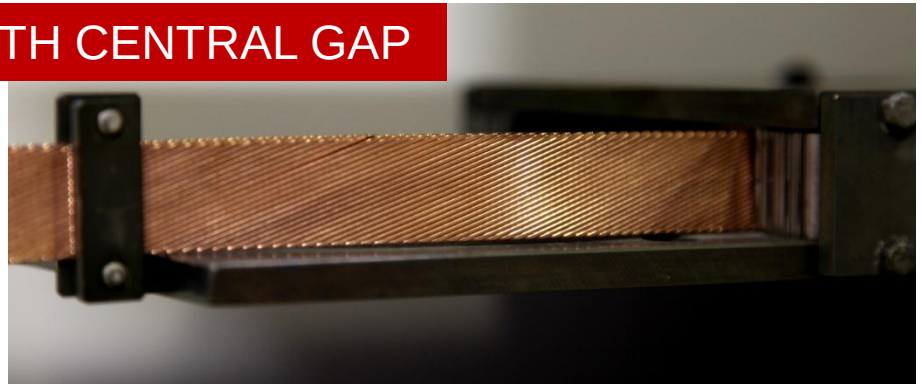
FIRST HEAT TREATMENT

CLOSED TITANIUM MANDREL

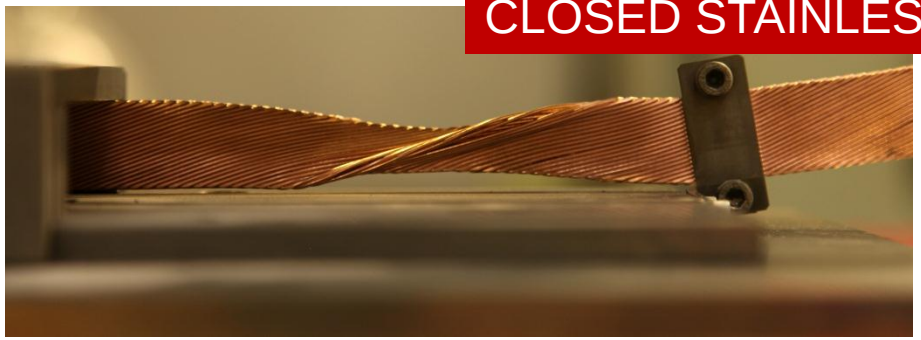


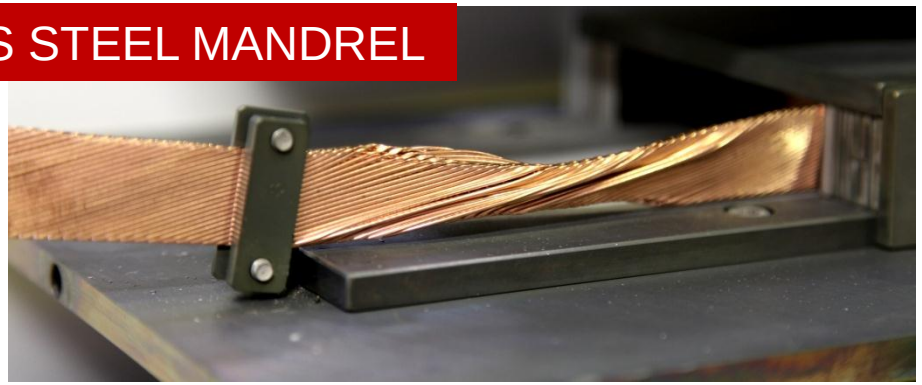


IRON MANDREL WITH CENTRAL GAP



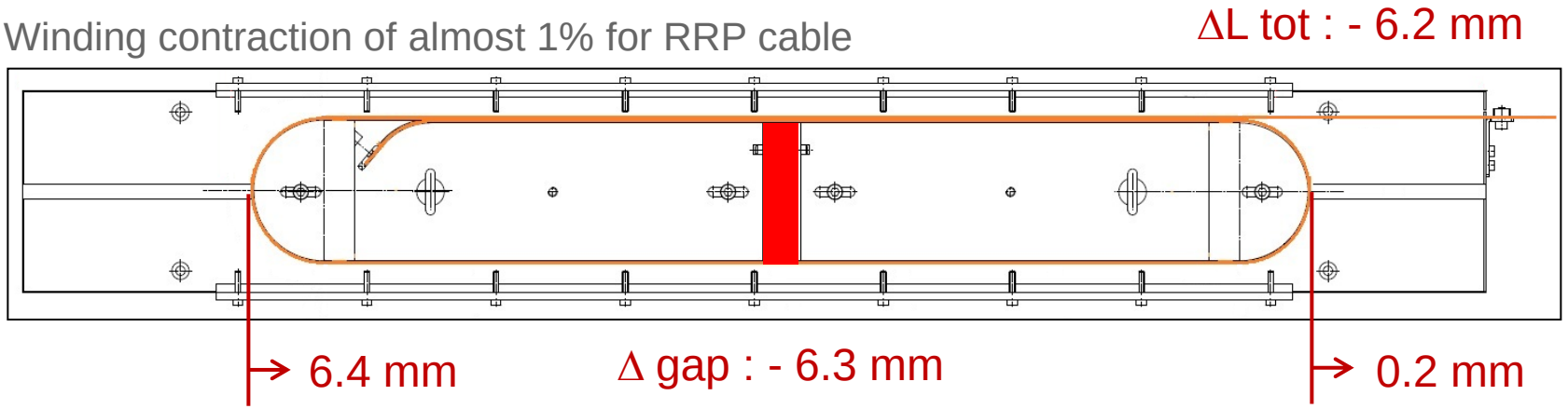
CLOSED STAINLESS STEEL MANDREL

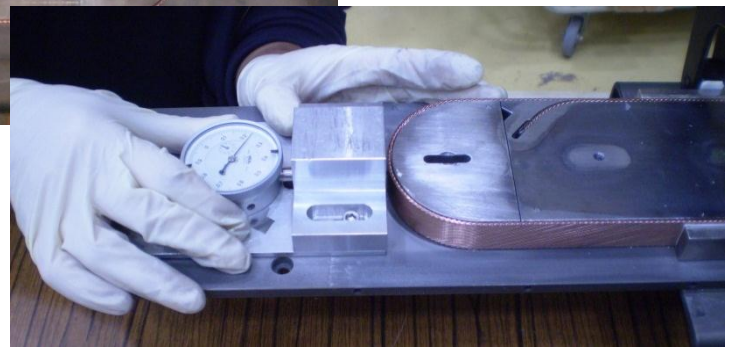




TT1 : IRON MANDREL – ONE CENTRAL GAP

- Mandrel was not fixed on lower plate during the heat treatment.
- Winding moved towards lead end.
- Winding contraction of almost 1% for RRP cable



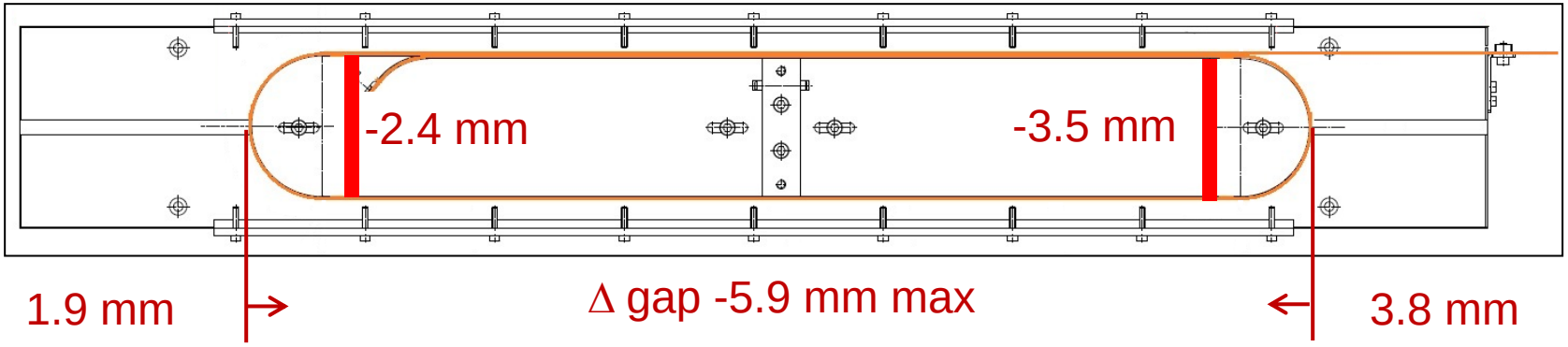


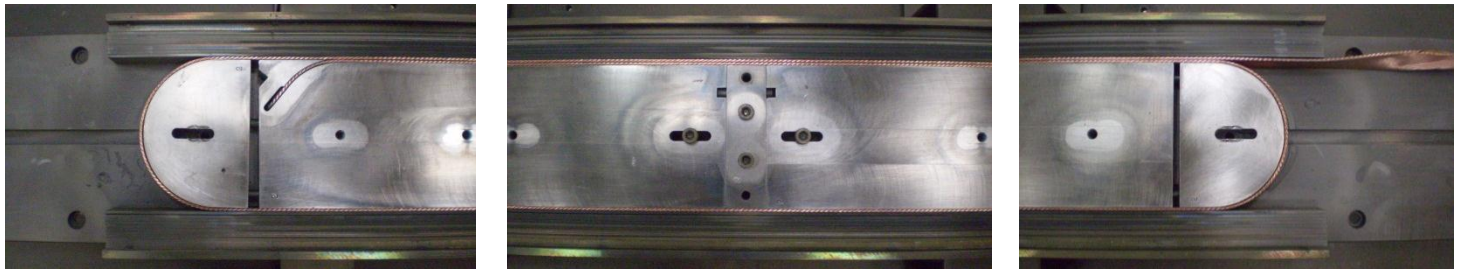
- Conductor dishing in the heads grew from 0.2 to 0.6 mm.

TT2 : IRON MANDREL – TWO HEAD GAPS

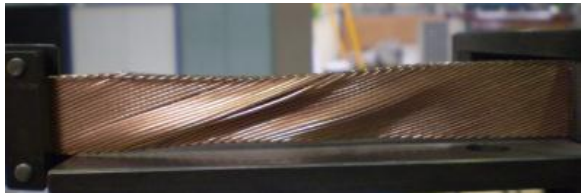
- 7.1 mm and 7.5 mm gaps had been left near the heads of the winding before the heat treatment.
- The straight sections of the mandrel were fixed on lower plate during the heat treatment, while the circular ones were free.

ΔL tot : - 5.7 mm



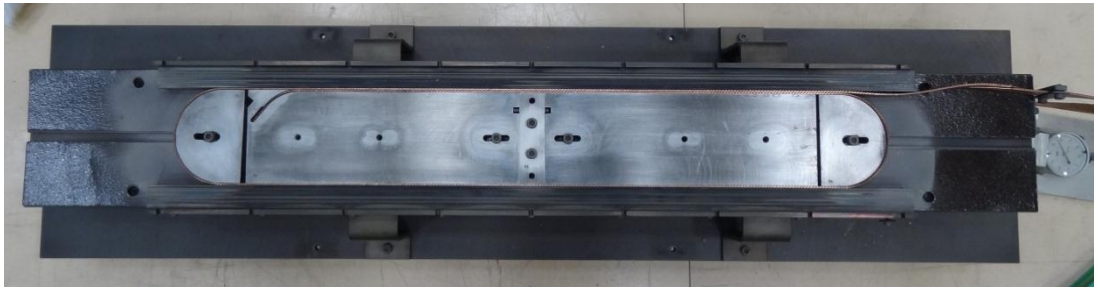


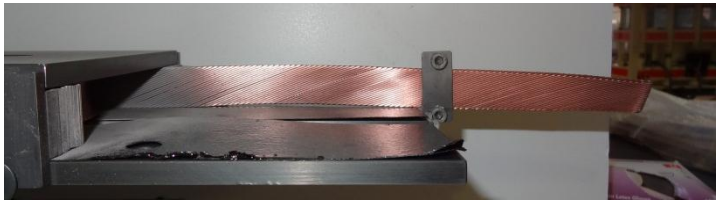
- The gaps closed of 5.9 mm towards the center of the winding but that was not enough to avoid tension stress on the cable near the lead end.
- Dishing in the head did not really change (from 0.2 to 0.3 mm).



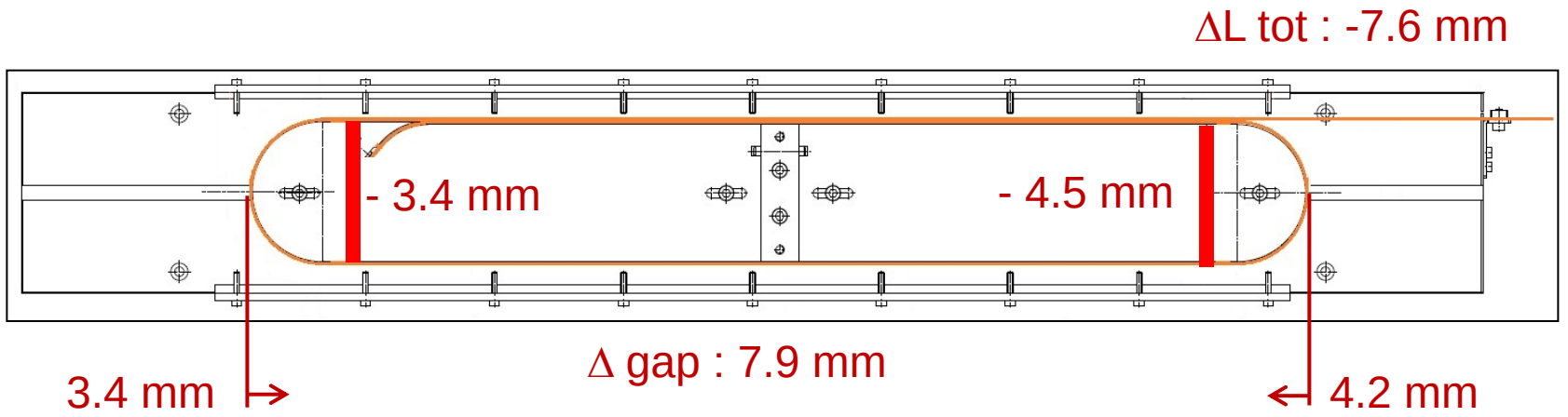
TT3 : IRON MANDREL – TWO HEAD GAPS

- Same configuration than previous test with two 7.7 mm gaps near the heads.
- A mica foil had been placed between the winding plate and the mandrel.





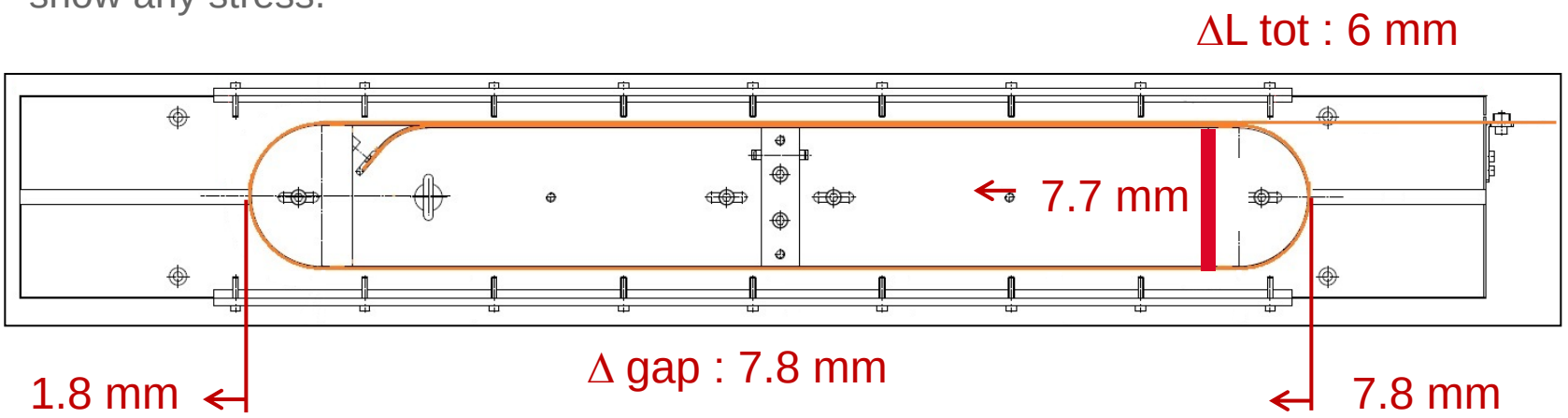
- The gaps closed of 7.9 mm and the cable near the lead end did not show any stress.



- Conductor dishing in the heads grew from 0.2 to 0.6 mm on LE side and to 0.45 mm on RE side
- A 1.6 mm gap appeared between conductor and mandrel appeared on LE side.

TT4 : IRON MANDREL – ONE SIDE GAP

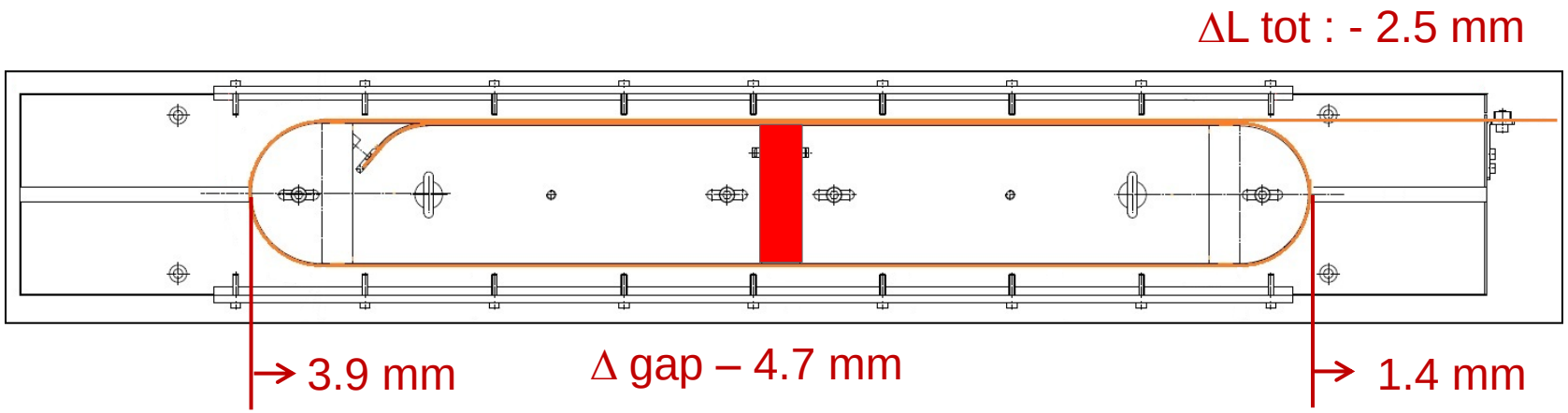
- A 16 mm gap had been left near the heads of the winding before the heat treatment.
- The straight sections of the mandrel were fixed on lower plate during the heat treatment, while the circular ones were free. A mica foil had been placed between the mandrel and the winding plate.
- The gap closed of 7.7 mm toward the center of the coil. The cable near the lead end did not show any stress.



- Conductor dishing in the heads grew from 0.2 to to 2.5 on LE side and from 0.3mm to 0.3 mm.
- 0.5 mm gap appeared in the head on the LE side Between the conductor and the mandrel
- 1.6 mm gap appeared in the head on the RE side.

RRP CABLE : TITANIUM MANDREL – CENTRAL GAP

- Mandrel was not fixed on the winding plate during the heat treatment.
- Winding moved towards lead end.



- Winding contraction of 0.3% for RRP cable

CONCLUSIONS

- Ten stack tests campaign is going to start in March.
- Tests will be carried out on RRP and PIT cables in order to compare their behavior .
- Results will allow to know the cable and insulation thicknesses, before and after reaction, and correctly dimension the reaction mold cavity for the FRESCA 2 Nb_3Sn coils.
- The dilatation behavior of RRP and PIT cable seems to be very different. Test campaign with RRP cable has to be continued as soon as possible to validate the first result.

To conclude test campaign on PIT cable :

- Second test with one gap on the lead side. This is the only solution we could applied to actual components and tools of FRESCA 2 coils.
- Test with an insulated cable
- One or more multi-turn test

THANKS FOR YOUR ATTENTION

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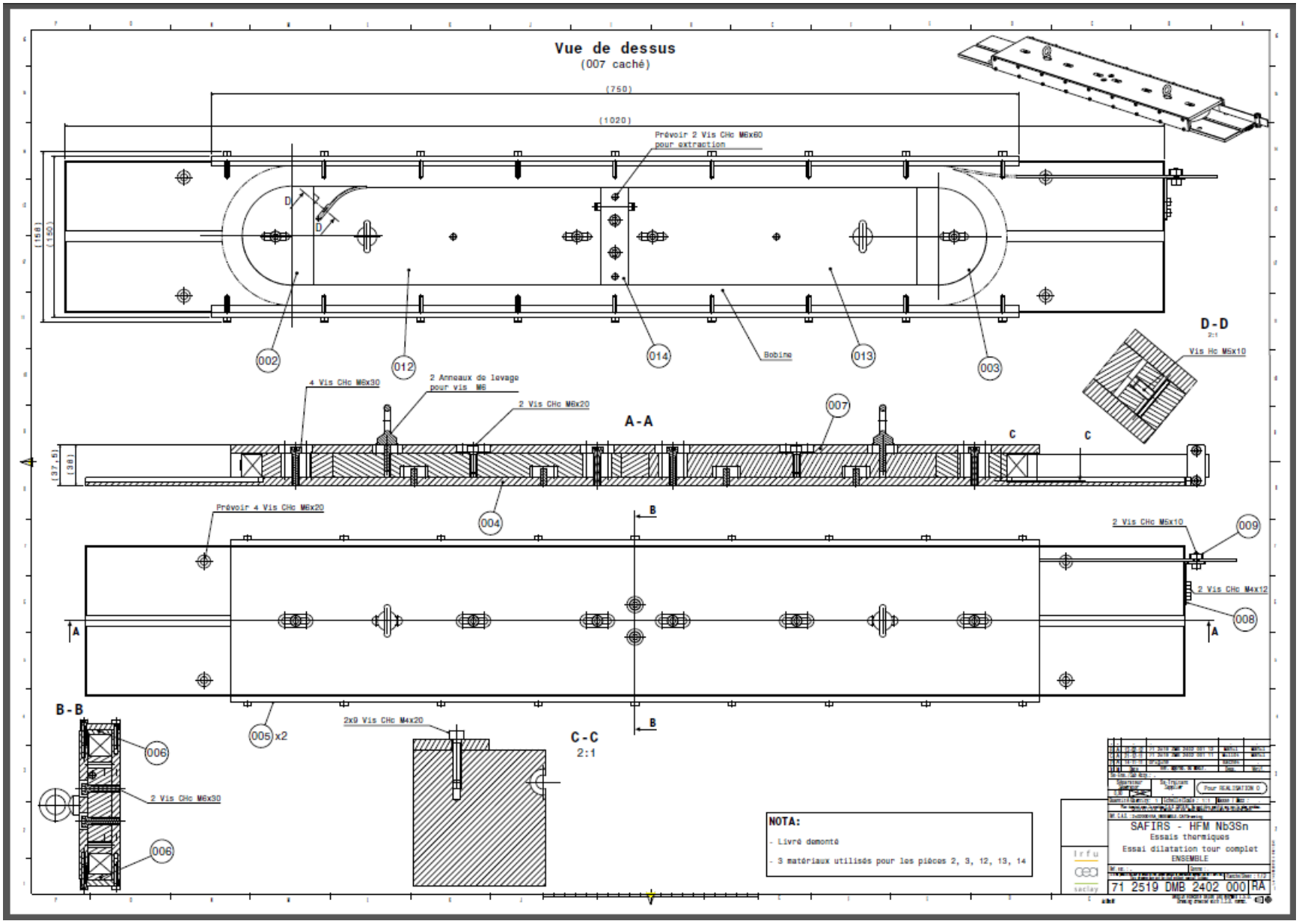
DILATATION TESTS TOOL



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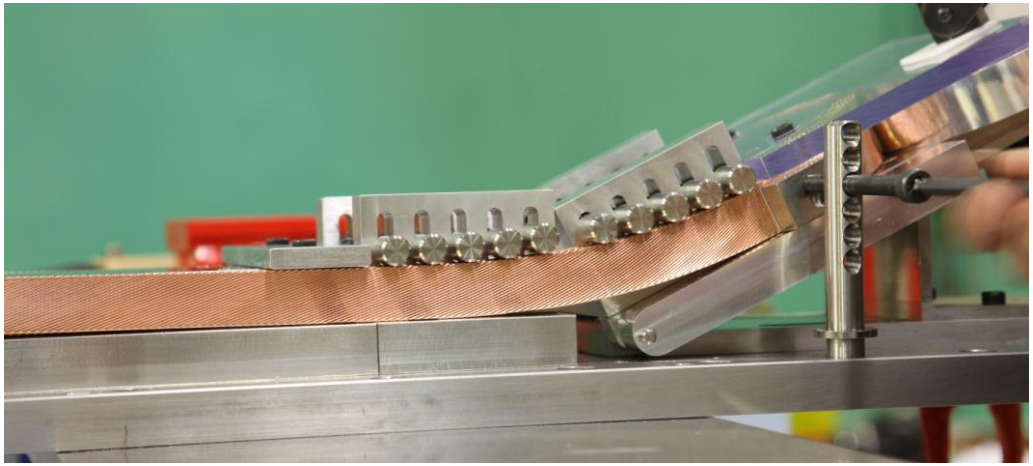
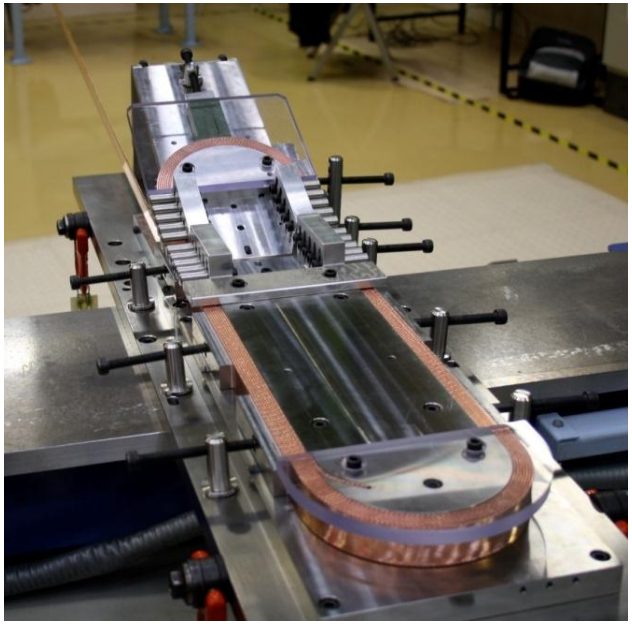
Preparatory activities have been foreseen before starting first Nb3Sn coil winding :

- **Winding tests to define end geometry**





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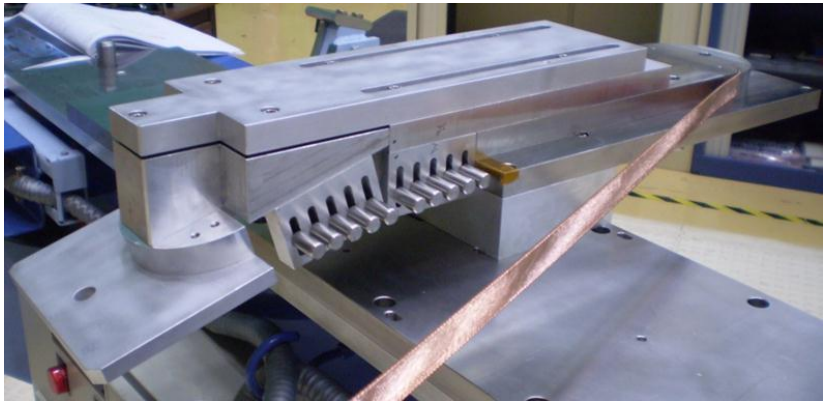

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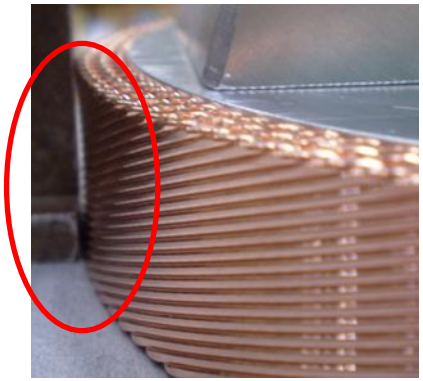
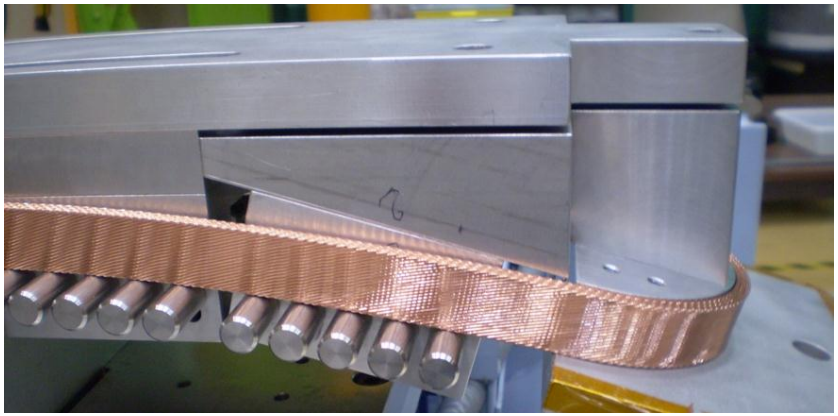


Dishing



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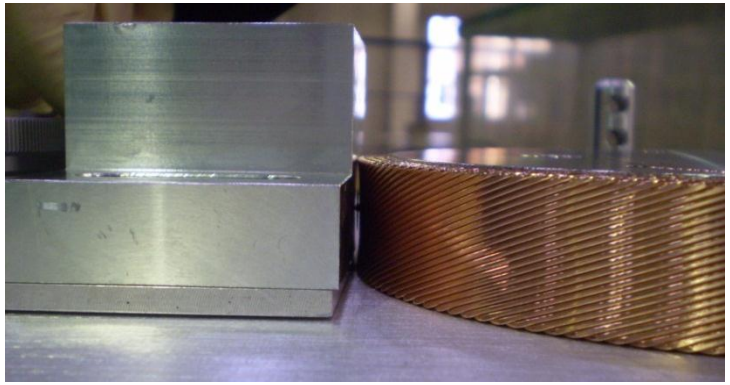

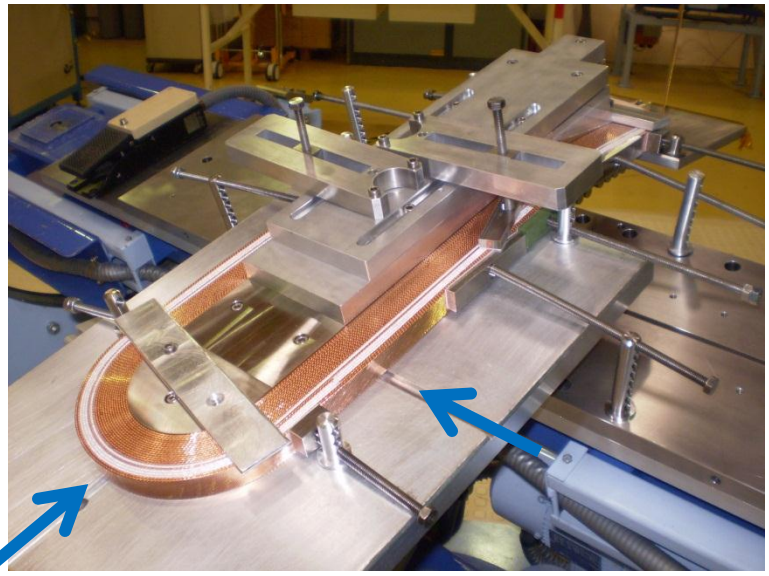

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