



Low Loss Rutherford Cable Development Status

Contract status of

- prototype wire
- Cored Rutherford Cable for Test Purposes
- Rutherford Cable for magnet winding

First ideas & design layout for the low loss wire @ Luvata Fornaci di Barga



Conductor development strategy



- **Prototype wire (fine filaments)**

concluded (see after)

- **Contract for the Cored Rutherford Cable for Test Purposes**

to manufacture a dummy Rutherford cable, in two units, the first **360 m** long and the second **420 m** long.

These units will be used for testing purposes.

in progress, cabling at New England Electric (USA) in June, delivery in July 07

- **Contract for superconducting Rutherford cable for magnet winding**

720 m (2 u.l.) of 1st generation Cable (3.5μ). These units will be used to wind shorter model magnets.

1080 m (3 u.l.) of 2nd generation Cable (2.5μ). Two units will be used for winding each of the two poles composing the 3 m long prototype magnet, while the third will serve as a spare.

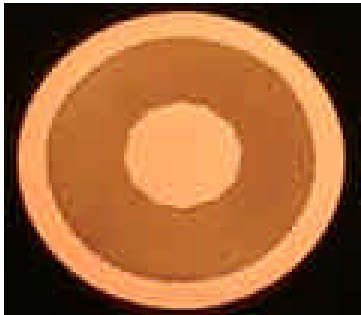
supplier selection in progress (see after)



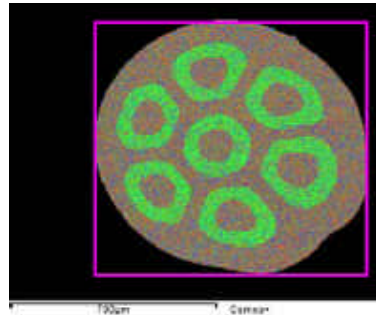
Prototype wire conclusions



A first 7 element assembly based on the OK3900 and cold drawing of the re-stack was attempted in June '06. Drawing presented problems, due to poor bonding between the NbTi and the copper matrix.



OK3900



7x

The prototype wire was meant only as a "test bench" to investigate the properties of fine filament wire, not to be a precursor of the final wire.

The good news is that $J_c = 2.500 \text{ A/mm}^2 @ 4.2 \text{ K}, 5 \text{ T}$ could be obtained on filament of 2.4 mm in diameter.



SC Rutherford cable for magnet winding contract



Formally not a R&D contract, *but*

- We distinguish between guaranteed values (e.g. I_c , filament diameter) and goals (ρ_t, R_a, R_c);
and we are

- open to discuss the effective outcome.

- In the supplier selection procedure, we have the freedom to select the potential suppliers (at least three). On April 26th, Call for Tenders were sent to:

Alstom (France)

EAS (Germany)

Luvata Fornaci di Barga (Italy)

Luvata Pori (Finland)

Luvata Waterbury (USA)

The rationale behind this choice was:

- to invite all the European Companies potentially capable/interested
- in addition, explicitly invite the only Company, which, to our knowledge, has manufactured in the past a wire very close to our goals

Answers are due by June 17



Wire specifications



Table I. Wire Main Characteristics.

Wire			Notes
Diameter after surface coating	0.825 ± 0.003	mm	
Filament twist pitch	$5 +0.5 -0$	mm	
Effective Filament Diameter for 1st Generation wire	3.5	μm	a)
Effective Filament Diameter for 2nd Generation wire	2.5	μm	a)
Interfilament matrix material	Cu-0.5 wt% Mn		
Filament twist direction	right handed screw (clockwise)		
I_c @ 5 T, 4.22 K	> 541	A	b)
n-index @ 5 T, 4.22 K	> 30		
Stabilization matrix	Pure Cu		
Strand transverse resistivity at 4.22 K	$0.4 + 0.09 B$ [T]	$\text{n}\Omega \cdot \text{m}$	
Cu+CuMn:NbTi ratio (α ratio)	>1.5		c)
α ratio tolerance	± 0.1		
Surface coating material	Staybrite (Sn-5 wt% Ag)		d)
Surface coating thickness d	0.5	μm	e)

Notes:

- a) As measured from magnetization.
- b) This is the primary value for virgin wire. It is 5% higher than the cabled values, to take into account degradation during cabling. It amounts, e.g., to 2.529 A/mm² for $\alpha = 1.5$ or 2.832 A/mm² for $\alpha = 1.8$, @ 5 T, 4.22 K.
- c) The supplier may propose an alpha value, provided it is larger than 1.5. Tolerance during the production must remain between ± 0.1 from the nominal value.
- d) Same coating material used for LHC dipoles.
- e) This is a preliminary value, to be better defined later.



Rutherford cable specifications



Table II. Cable Main Characteristics.

Geometrical			Not
Strand Number	36		a)
Width	15.10 +0 -0.020	mm	
Thickness, thin edge	1.362 ± 0.006	mm	
Thickness, thick edge	1.598 ± 0.006	mm	
Mid-thickness at 50 MPa	1.480 ± 0.006	mm	
Edge radius	= 0.30	mm	
Core material	AISI 316 L stainless steel, annealed		
Core width	13	mm	
Core thickness	25	μm	
Transposition pitch	100 ± 5	mm	
Cable transposition direction	left-handed screw thread		
Electrical			
Ic @ 5 T, 4.22 K	>18,540	A	b)
Stabilization matrix RRR	>70		

Notes:

- a) The geometrical layout is the same as that of the LHC dipole outer cable design. Dimensions are specified at 20 °C.
- b) Ic @ 5 T, 4.22 K for the extracted strand must be equal to or above 515 A.



A preliminary design: transverse resistivity, results

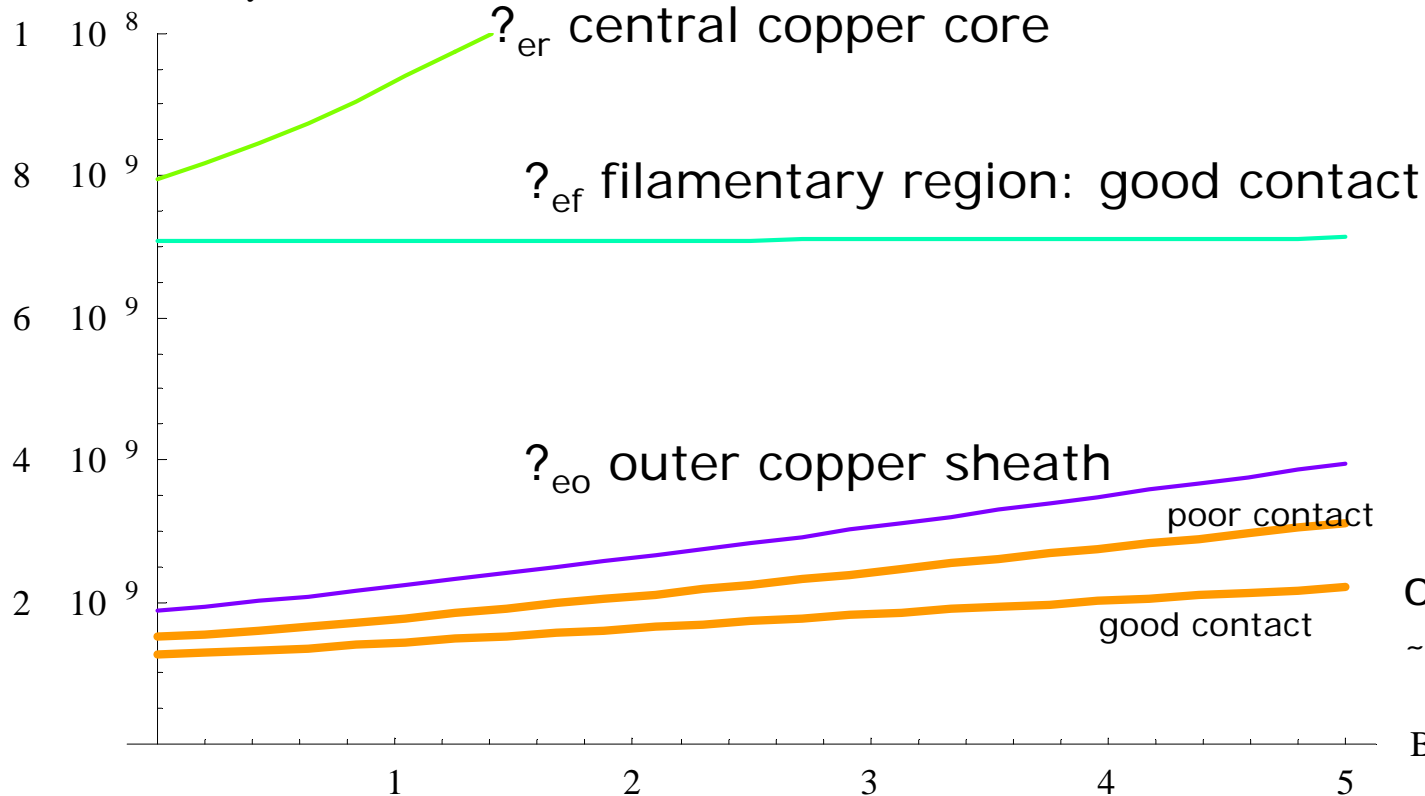


$1.3 \cdot 10^{-7} \text{ O}\cdot\text{m}$



ρ_{ef} filamentary region: poor contact

Transverse resistivity [μm]



overall ρ_t

$$\sim 1.5|1.6 + 0.19|0.33 \cdot B \text{ nO}\cdot\text{m}$$

B [T]



To be compared with $0.4 + 0.09 \cdot B \text{ nO}\cdot\text{m}$ specified, based on "A" design



A preliminary design: dynamic stability



Nonetheless, the stability criterion seems satisfied, whatever the choice made

Thermal conductivity

Weighed average between NbTi and CuMn 1.02 W/mK

Approach "à la Carr" 0.53 W/mK

λ (NbTi fill factor in the bundle)

0.516

J_c @ 4.2 K, 5 T

2500 A/mm²

ρ_{Cu} 4 · 10⁻¹⁰ ohm m

Characteristic length 37 μ m

Round filament factor form $4\sqrt{2} \cdot 37$ 211 μ m

$$d_{st} = \sqrt{\frac{k \cdot (\theta_c - \theta_o) \cdot (1 - \lambda)}{\lambda \cdot J_c^2 \cdot \rho}}$$

equivalent diameter $\ll 4 \cdot \sqrt{2} \cdot d_{st}$

Equivalent macrofilament

Smallest 63 μ m

Largest 140 μ m

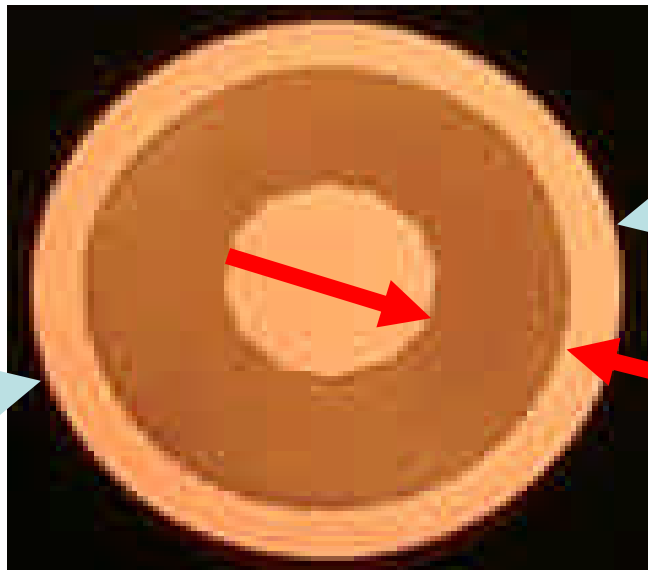
So the margin for stability seems smaller compared to the layouts envisaged by MNW in Rep 29, needs to be further investigated



A preliminary design: dynamic stability



OK3900



0.575 mm

0.118 mm

0.808 mm

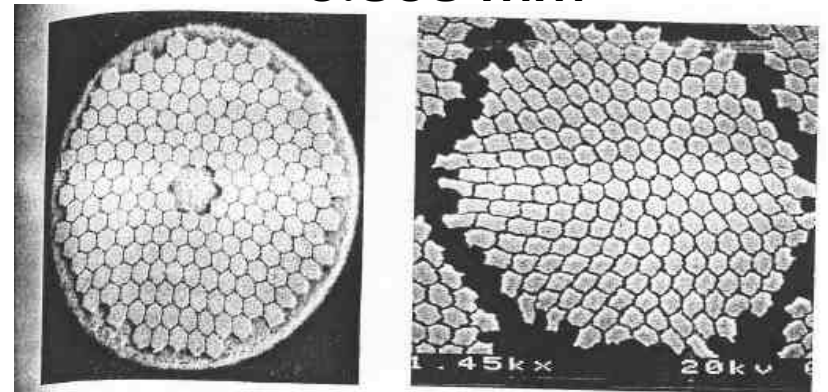


Fig. 2. Inner grade conductor at 0.808 mm dia. containing 38,208 - 2.5 micron filaments.

0.648 mm

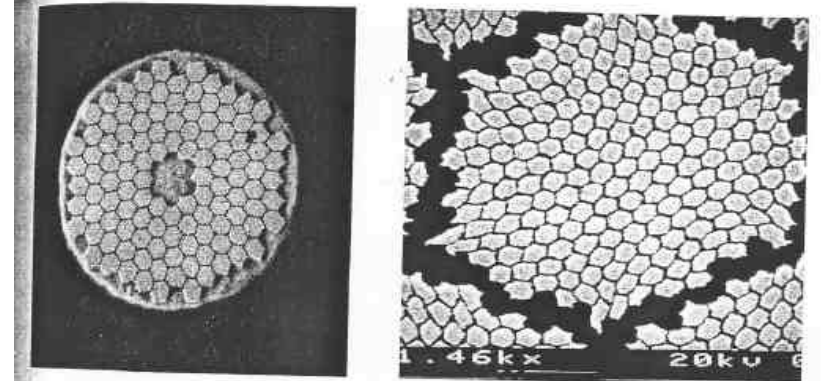


Fig. 3. Outer grade conductor at 0.648 mm dia. containing 22,686 - 2.5 micron filaments.

CONDUCTORS WITH 2.5 MICRON NbTi FILAMENTS
H. C. Kanithi, P. Valaris and B.A. Zeitlin
IGC Advanced Superconductors Inc.

Supercollider 3



Open/Hot(Cold?) issues



Cold drawing/extrusion

- is it really reliable?
- it introduces an "unbalance between 1st and 2nd assembly
- less bonding?, more prone to degrade at smaller twist pitch?

On the other hand, reportedly, cold drawing leads to:

- less sausaging
- smaller alpha variation along wire length

Central copper core, minimum size

With present design "C-like", τ_t is **4 times higher than specs**, is that really necessary?

In my opinion **dynamic stability** is the most critical issue

... and still to be discussed:

SnAg layer thickness

Cabling issues (experience of July test awaited)



Conclusions



Call for tenders launched, answers by June 17

Companies start to be involved in technical discussions, problems analyzed and possible solutions discussed.

Based on a not-very-high critical current density on finer filaments, we are considering design with lower matrix content: what is the impact on the wire stability?

Issues related to coating/cabling not yet considered