LARP Cable R&D FY05 & FY-06 Plans

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LARP Port Jefferson
April 6-8, 2005

Cabling Tasks for FY-05

- Proto-type cable for TQ to establish TQ cable parameters
  - 26, 27, 28 Strands
  - Keystone Angles of 1.0 and 1.3 degrees
- Cable for TQ magnets
  - Practice winding
  - Production
- Cable for SQ-02

TQ Cable Parameters

Parameters	Units	TQ Prototype	Tolerance	
Strands in cable	No.	26 or 27	NA	
Strand diameter	mm	0.7	+/- 0.002	
Width	mm	10.077 max.	+0.000, -0.100	9.977 min
Thickness	mm	1.26	+/- 0.010	
Keystone angle	deg.	1.0	+/- 0.10	

Cable Parameter Matrix for TQ-01

	No. of Strands		
Keystone Angle	**26**	**27**	**28**
1.0	**X**	X	X
1.3	X	X	X

Cable R&D : Modify Strand Mechanical Behavior

- Present Nb_3Sn cabling procedure at LBNL

  (Coils for RD-3b, RD-3c, HD-1)

  1. Fabricate cable
     1. Slightly over size
  2. Anneal at 200°C/2-4h
     1. Softens Cu and cable contracts by ~0.25% in length
     2. May harden Sn core
  3. Re-roll to decrease thickness by 25-50 μm.
     1. Compacts cable making it mechanically stable

- Plan to follow same procedure for LARP

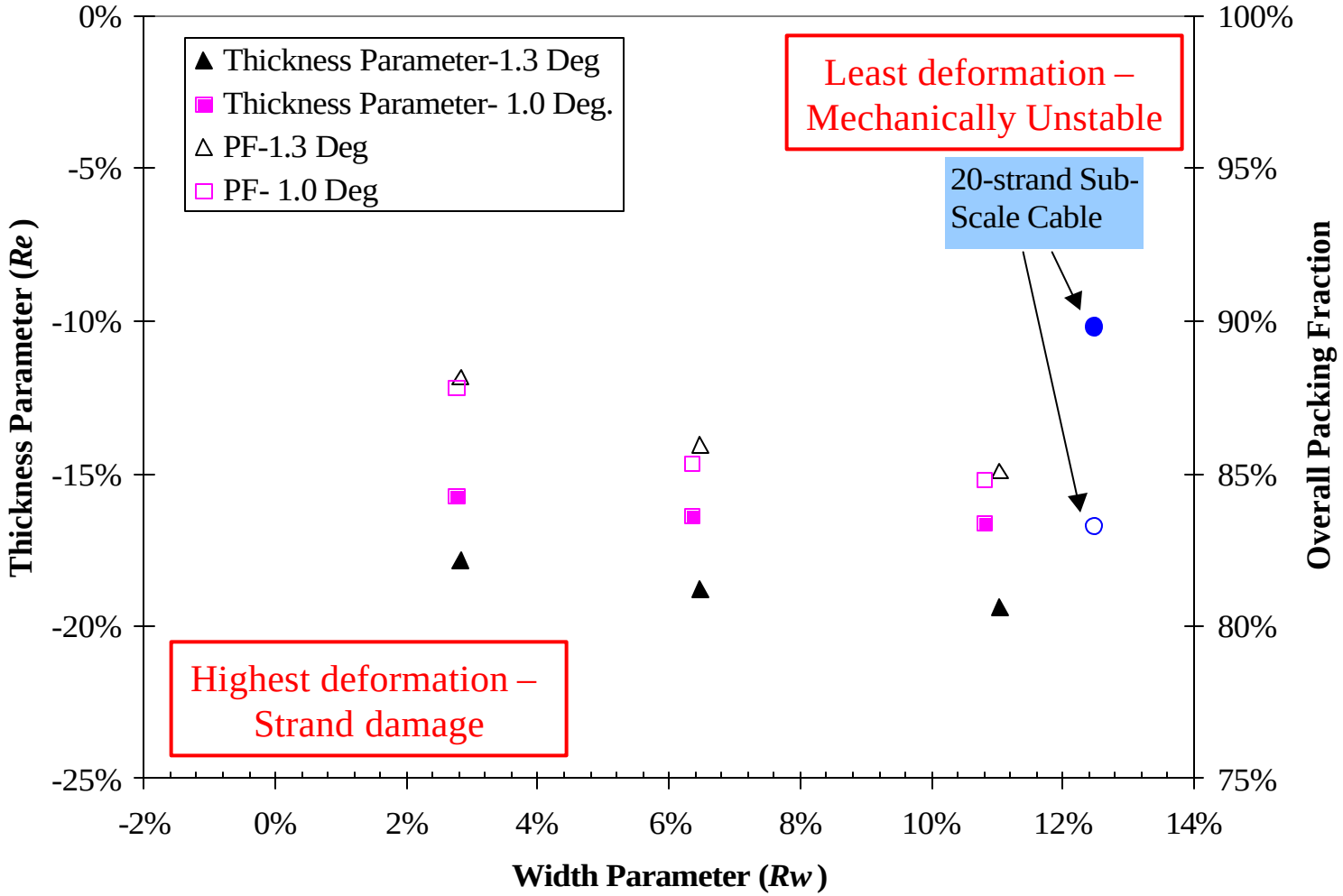
Cable 913 (1.0 deg. KS)

Strand:	ORe 206-C
Diameter:	0.705mm
Non-Cu:	0.53

- FINISHED CABLE -

	913R-A	**913R-B**	**913R-C**
No. of Strands	28	27	26
Pitch length mm	80	80	62
First Pass Keys / Keys	K	K	K
FINISHED LENGTH:	1.75		
Avg. THICKNESS:	1.274	1.267	1.265
Avg. WIDTH:	10.033	**10.012**	9.981
Avg. ANGLE:	1.019	**1.047**	1.058
Tail ends metallography	x	x	x

Cables 910 and 913 Deformation Parameters



Edge Facets of Cable 913: 1.0° KS

Thin Edge Thick Edge

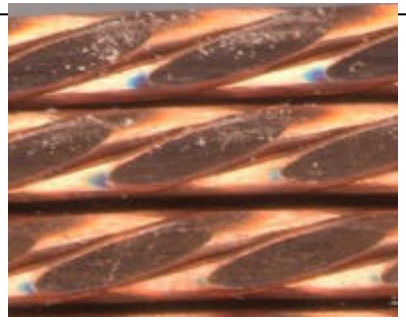
913R-A
28 strands

913R-B
27 strands

913R-C
26 strands

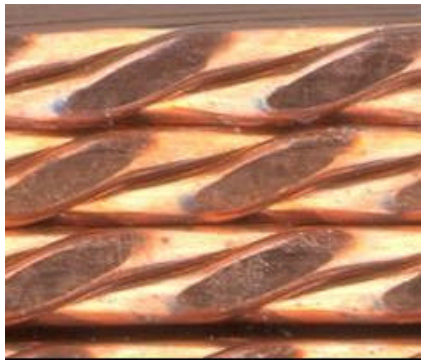
Edge Facets of Cable 910: 1.3º KS

Thin Edge Thick Edge



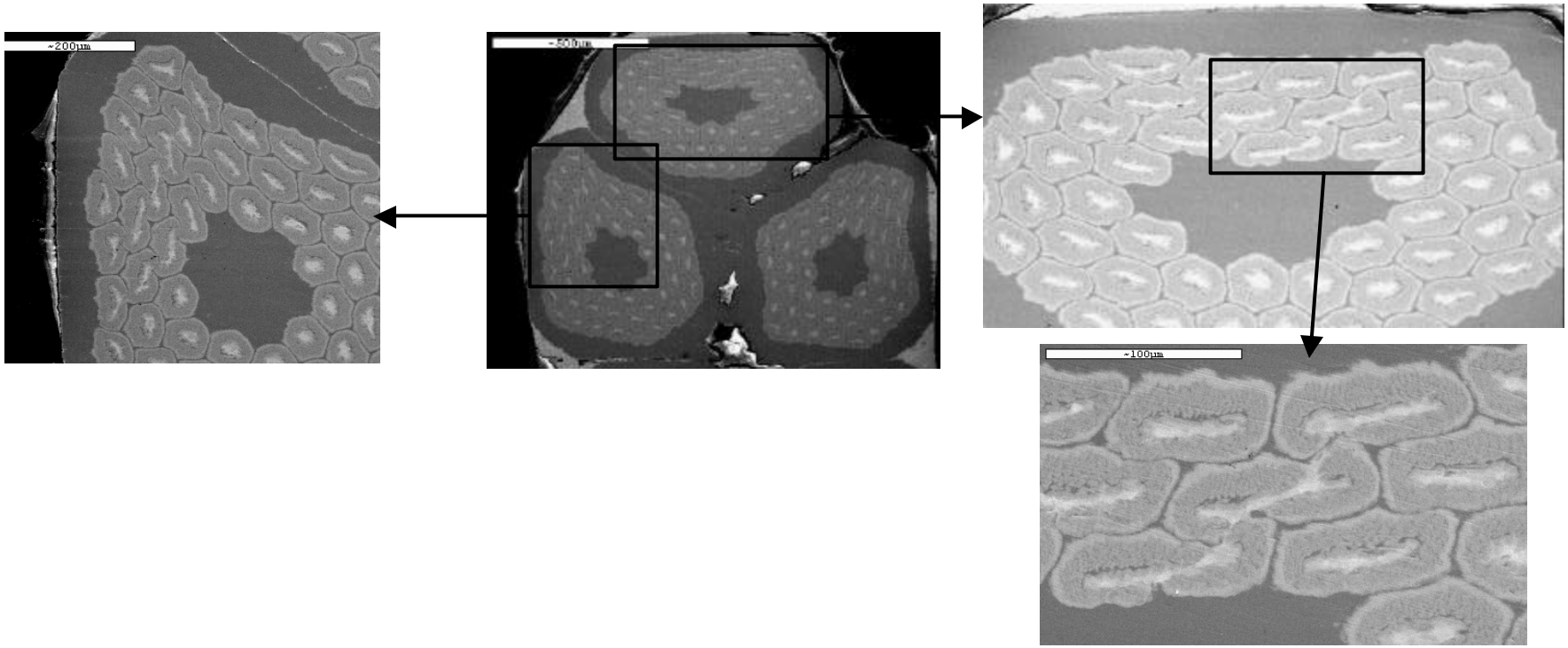
910R-A
28 strands

910R-B
27 strands



910R-E
26 strands

913R-A: 28 Strand Cable



Composition of Cu Stabilizer after Heat Treatment

- Cu-Sn composition

Position #6 inner

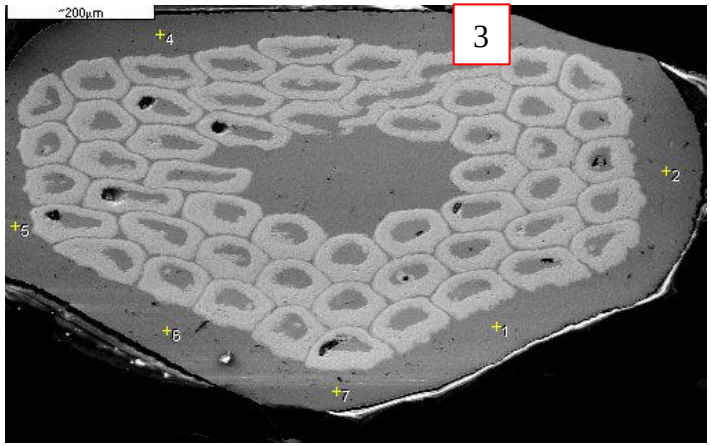
Elmt	Atomic %
Cu K	95.23
Sn L	4.77
Total	100.00

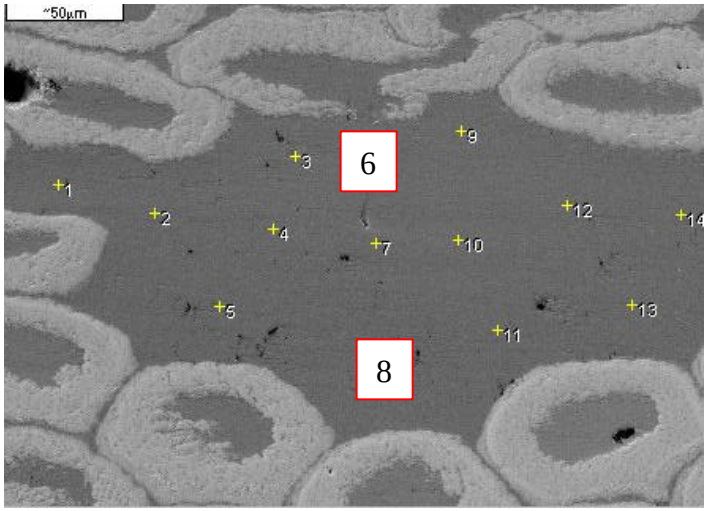
Position #8 inner

Elmt	Atomic %
Cu K	99.19
Sn L	0.81
Total	100.00

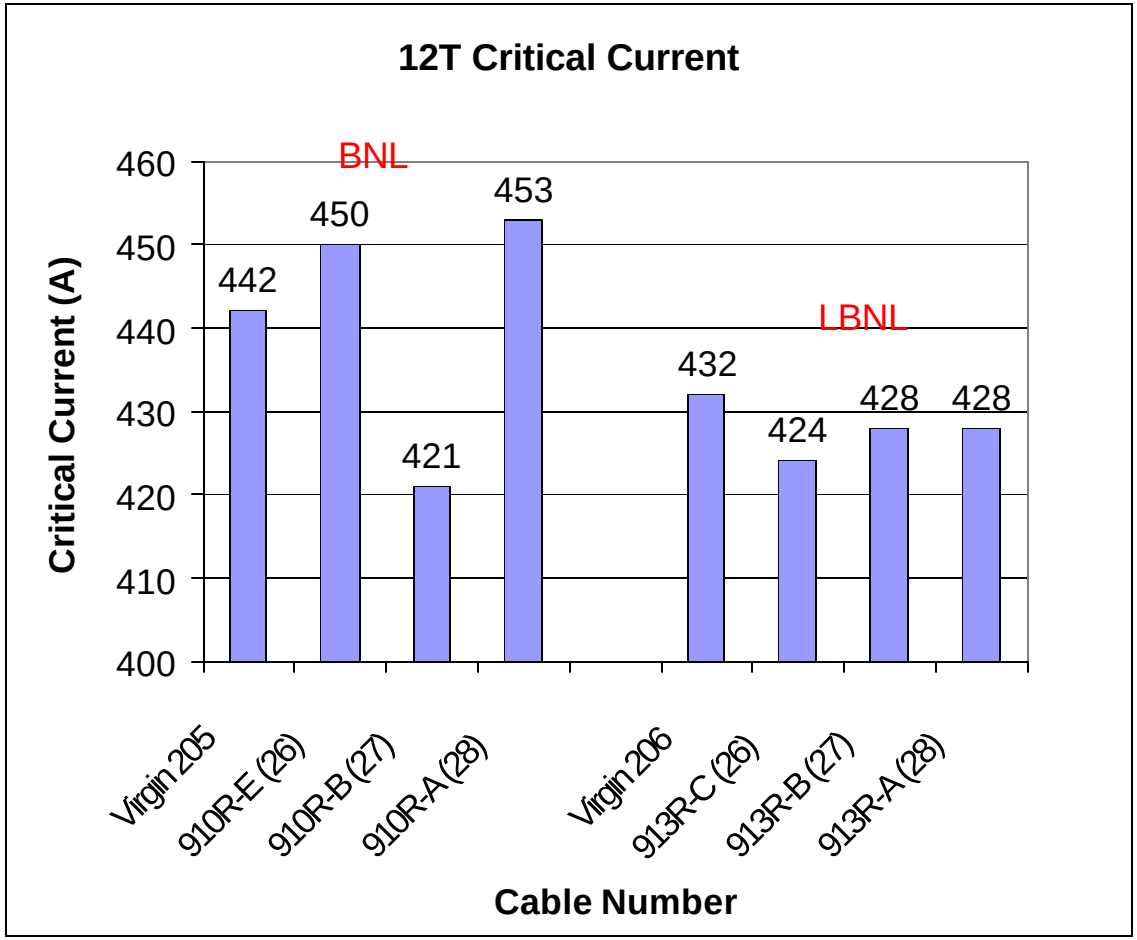
Position #3 outer

Elmt	Atomic %
Cu K	99.19
Sn L	0.81
Total	100.00

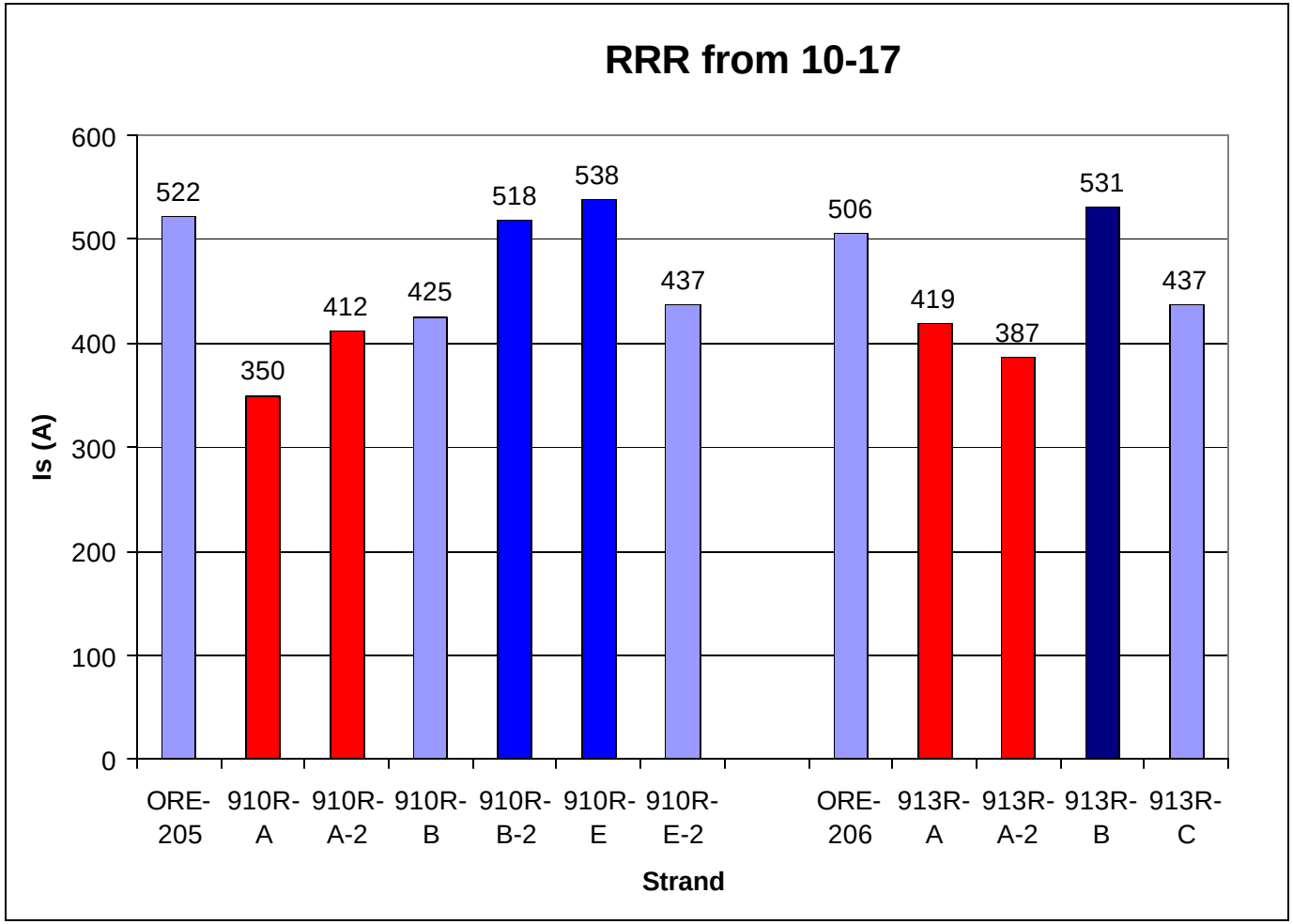




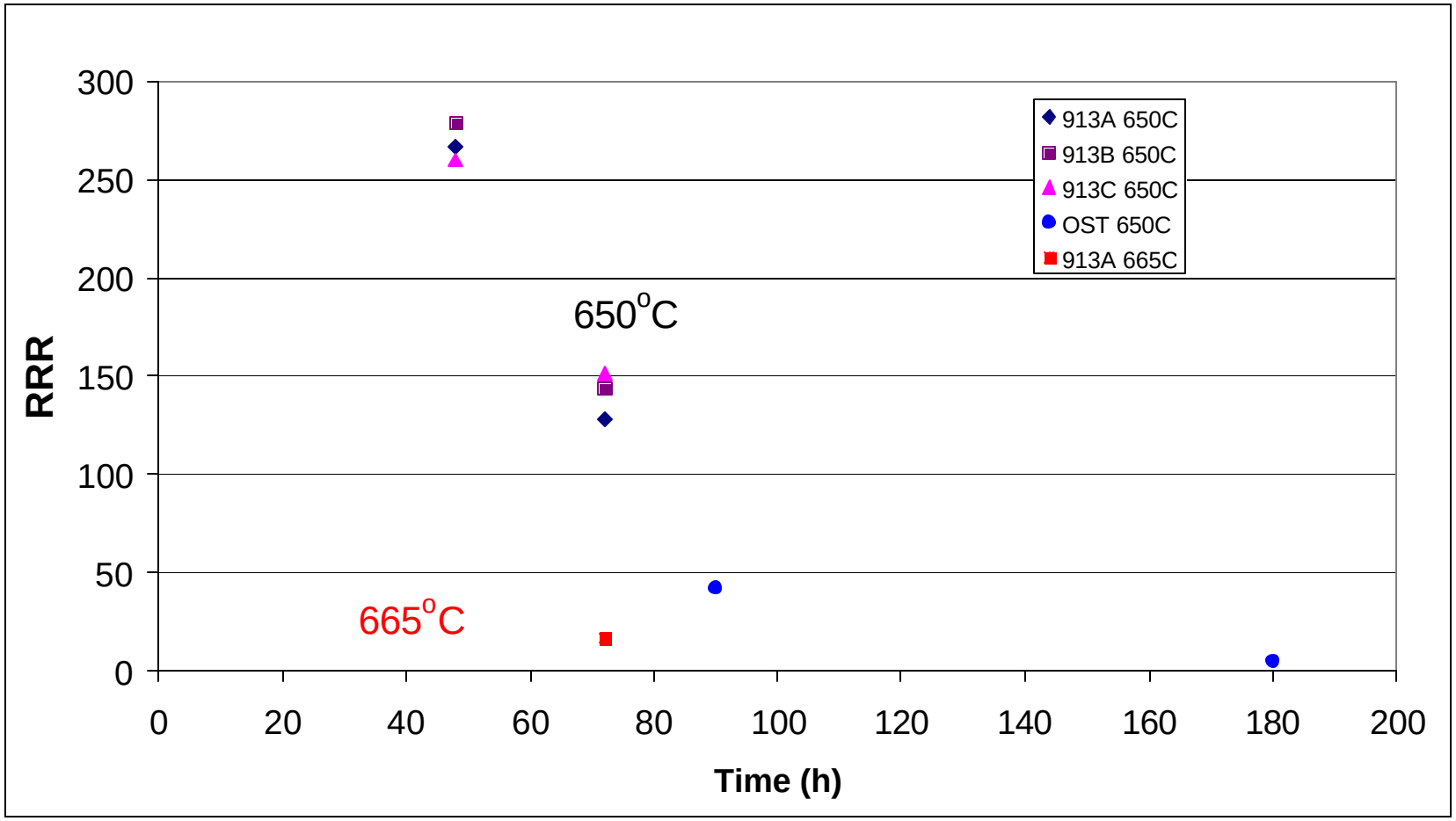
Critical Current of Strands Extracted from Cable 913



Strand Stability

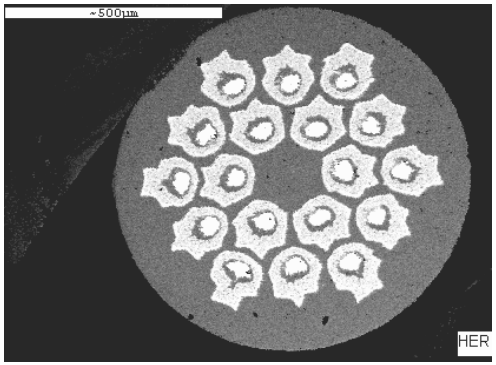


RRR of Strand 206

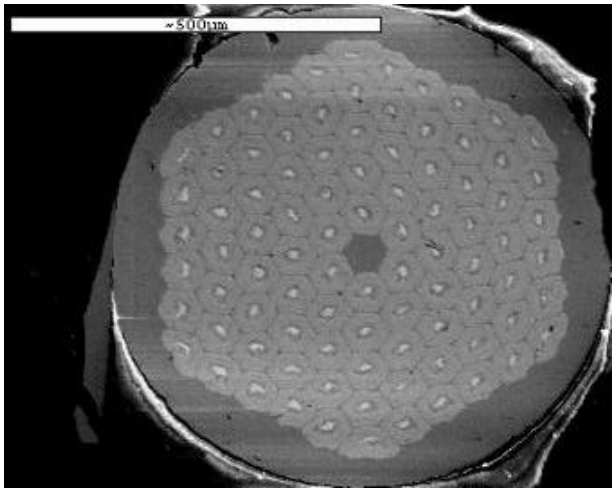


Cable for Practice Winding

- HER strand from HEP Inventory
  - Has been drawn from 0.8mm to 0.7mm at LBNL and is ready to be placed on cabling spools.
  - Strand length is ~6,000m
  - Can make at least 3UL



Possible Strand for TQ1a



Strand 8079 90/91 stack

Conductor needed: 25kg minimum

Jc (12T, 4.2K): 2,000-3,000A/mm^2

RRR: >50

Stability Current I_s(4.2K): >650A

Billet	Type	Stack	Diameter (mm)	Weight (kg)		Magnet
7933	RRP	60/61	0.7	**25.7**	$	TQ
7946	RRP	60/61	0.7	**22.7**	$	TQ
8079	RRP	90/91	0.7	**21**	R&D	TQ

B8079 90/91 0.7mm	
ID B8079-	L(m)
1	912
2	909
4	274
5	211
7	1242
tot L(m)	3548
tot wt(kg)	12.1

Strand for TQ Magnets

- I propose that both TQ magnets be made from MJR strand from the FNAL inventory.
  - Cable parameters have been determined
  - Strand performance is understood
  - Strand availability and strand characterization is moved from the critical path
  - Provides the best comparison of the two magnets

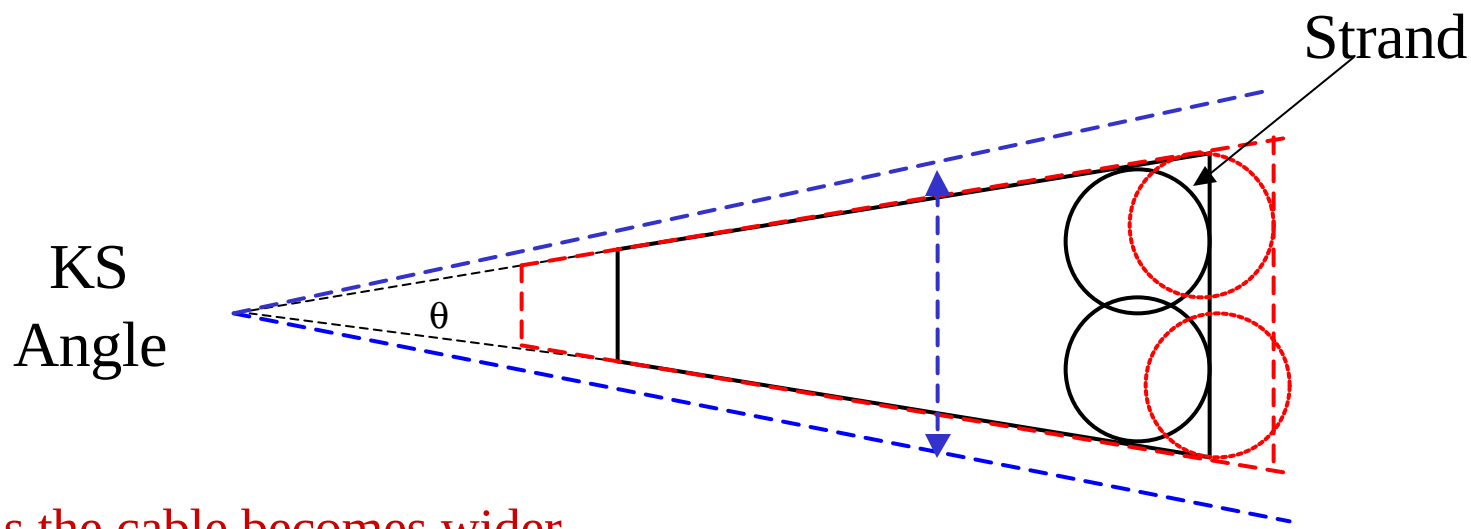
FY-06 R&D Effort

- Fully key-stoned wide cables
- Transverse loading vs. I_c of cables
- Mini-cable for studying strand cabling behavior
- Residual twist in cables

FY-06 – Wide Cables

1. Wide cable R&D (~15mm wide)
   - Determine limits of keystone angle
2. Explore the use of thin cores in the cable to increase the cables mechanical stability.
   - Solid core
     - May not be flexible for winding
   - Cable of Cu strands
     - Could introduce a SS core

Wide Cables



As the cable becomes wider

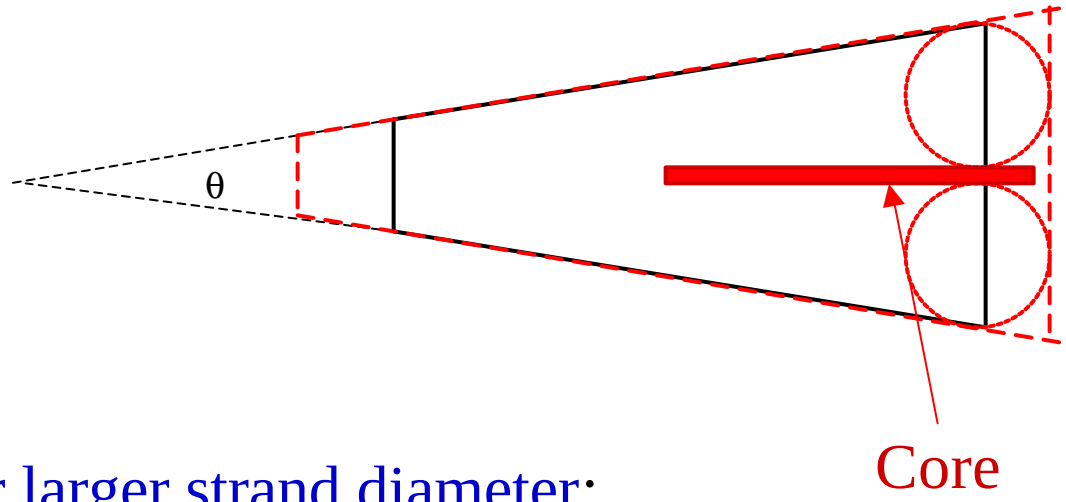
- Minor edge is more compacted
- Major edge is less compacted

For larger strand diameter:

- Cable mid thickness increases
- Keystone angle increases

Wide Cables (Cont.)

KS Angle



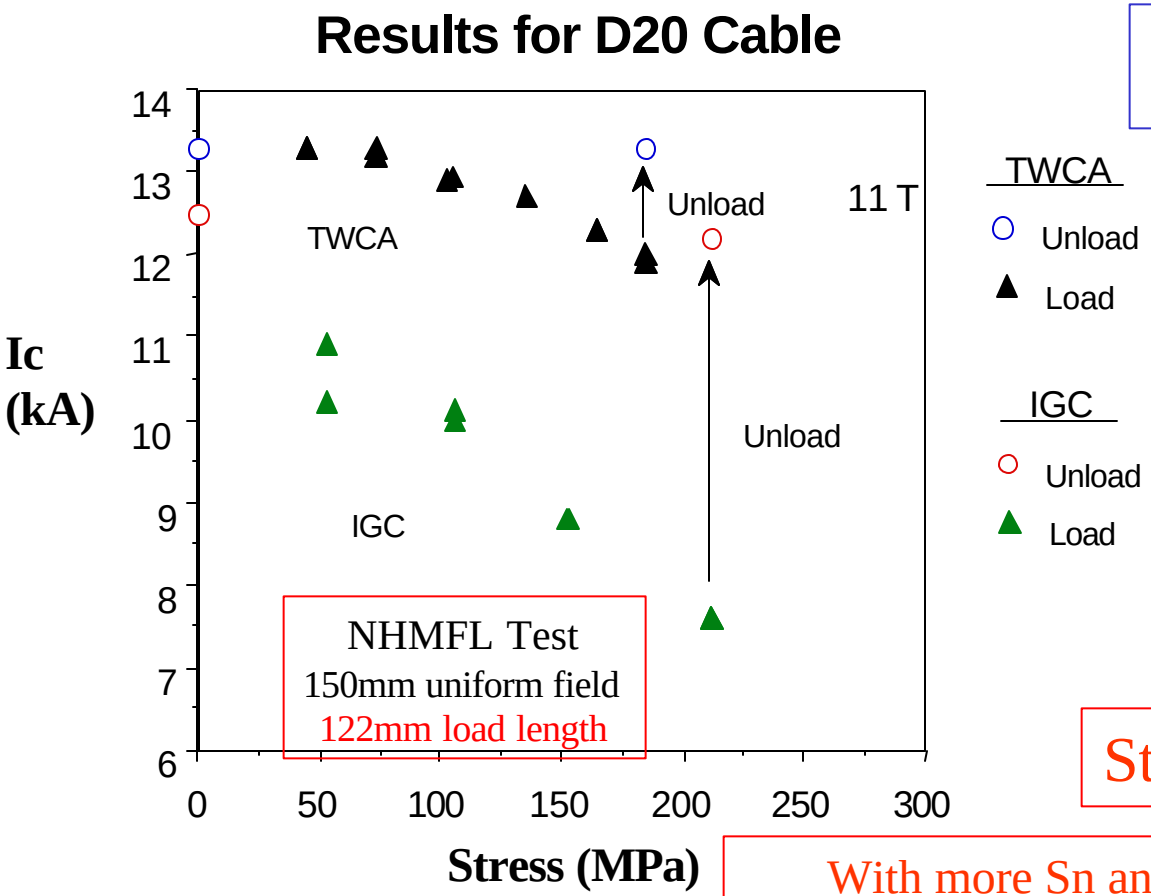
For larger strand diameter:

- Cable mid thickness increases
- Keystone angle increases

Transverse Loading Tests at NHMFL

- Cables in magnet environment
- In 1 week can test 3-4 cable-pair samples
- NHMFL covers all costs but LHe ~$5k-10k

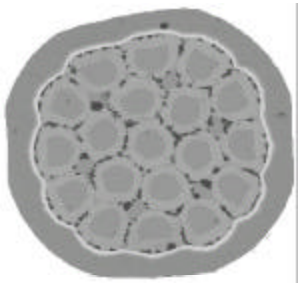
Sensitivity of Cables to Transverse Stress



MJR recover Ic when unloaded

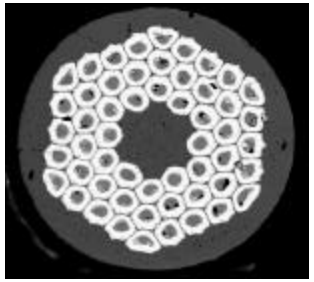
D-20

LBL Cable # 523
MJR-TWCA



LBL Cable # 522
IGC-Int. Tin

HD-1



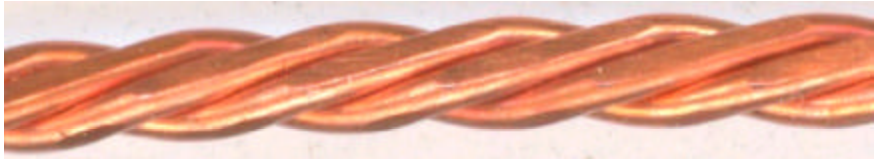
RRP-Oxford

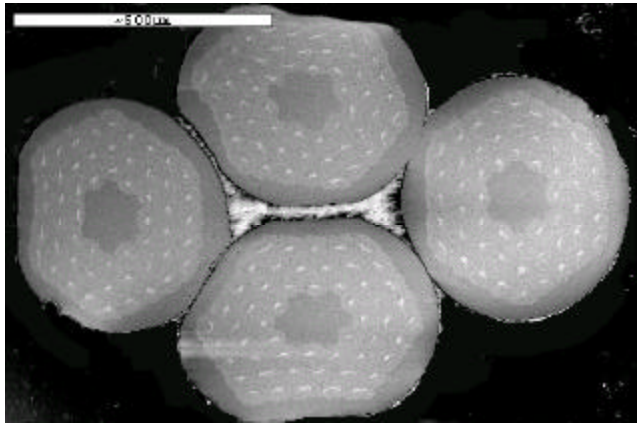
Stress Issue?

With more Sn and Nb in the sub-elements Nb_3Sn filaments sinter

4 Strand Cable

- Use much less material
- Shorter Pitch Length provides more strand edges
- Tooling independent of main cabling machine
- Correlate edge and face facet size to strand deformation.
- I_c(12T, 4.2K) ~2,000A
  - Can test cable or
  - Extracted strand if current too high

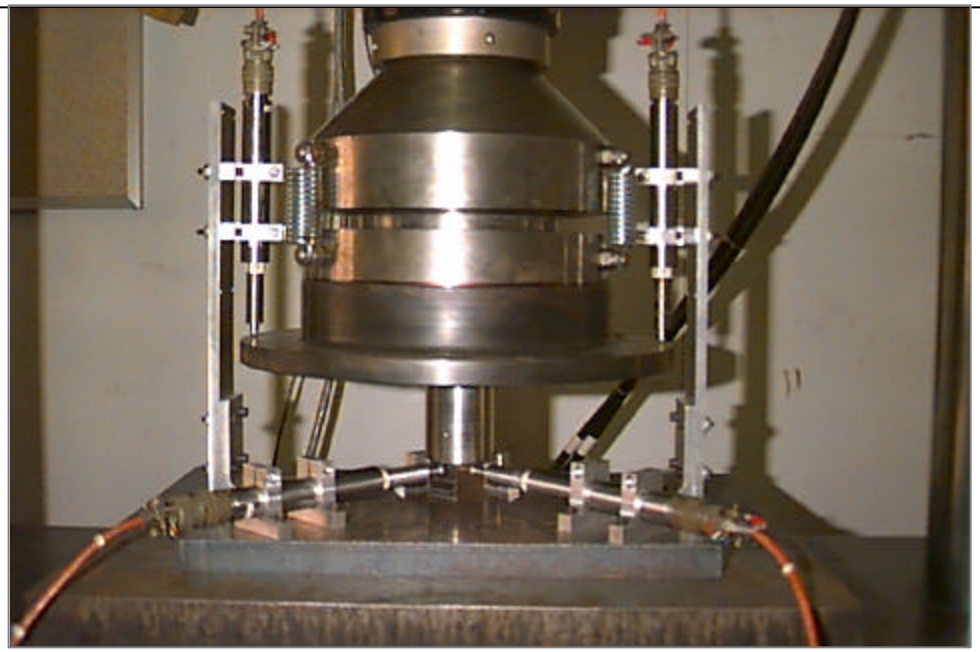




Residual Twist in Cable

- Residual twist in a cable after fabrication and after heat treatment may be an issue for long magnets.
- Want to develop a cable with minimal twist
- Heat treat straight cables and measure the residual twist
  - If it is determined to be an issue then:
    - Vary spool and planetary rotation
    - Effects of annealing and re-rolling
    - Heat treat straight cables and measure the residual twist

Mechanical Testing Of Magnet Materials



MTS Tension/Compression Tester
Instron 8500 Plus Controller, Labview DAQ

50 Kip Capability, 6” total stroke (±3.0”)
Cryogenic testing at 77K

S. Bartlett

FY-06 Funding

Conductor costs not included: ~$255K

- 2 TQ magnets. $30k
- 1 SQ ~$15k.
- Rad-hard Cu cable ~$10k
- One Long magnet cable ~$15k
- Cosine Theta mirror
  - Cu cable ~ $30k
  - Nb_3Sn cable $30k

- 2-3 R&D cable runs for new strand ~$45k
- Fully key-stoned wide cables studies ~30k
- Cabling testing at NHMFL with sample fabrication costs ~$50k
- Stand testing at LBNL for the above studies?

End

TQ Candidate Strands in CDP/HEP Inventory

CDP/HEP R&D

Billet	Stack Type	Jc (12, 4.2K)	Wire Diameter (mm)	non-Cu (%)	RRR	Twist	HT	Note
7933	60/61	2362	0.7	**59**	?	?	210C/48h+400C/48h+570/36+695C/50h	
7933	60/61	2325	0.7	**59**	?	?	210C/48h+400C/48h+570/36+695C/50h	
7946	60/61	2076	0.7	**59**	130	?	210C/48h+400C/48h+650C/**50h**	Low-n
7946	6061	2140	0.7	**59**	21	?	210C/48h+400C/48h+650C/**75h**	Higher-n
8079	90/91	2339	0.7	**59**	280	?	210C/48h+400C/48h+**635C**/40h	
8079	90/91	2427	0.7	**59**	34	?	210C/48h+400C/48h+**675C**/100h	

CDP/HEP Purchase

XXXX	54/61	2800	0.7	50%	>50	April or May delivery

Nb_3Sn Inventory

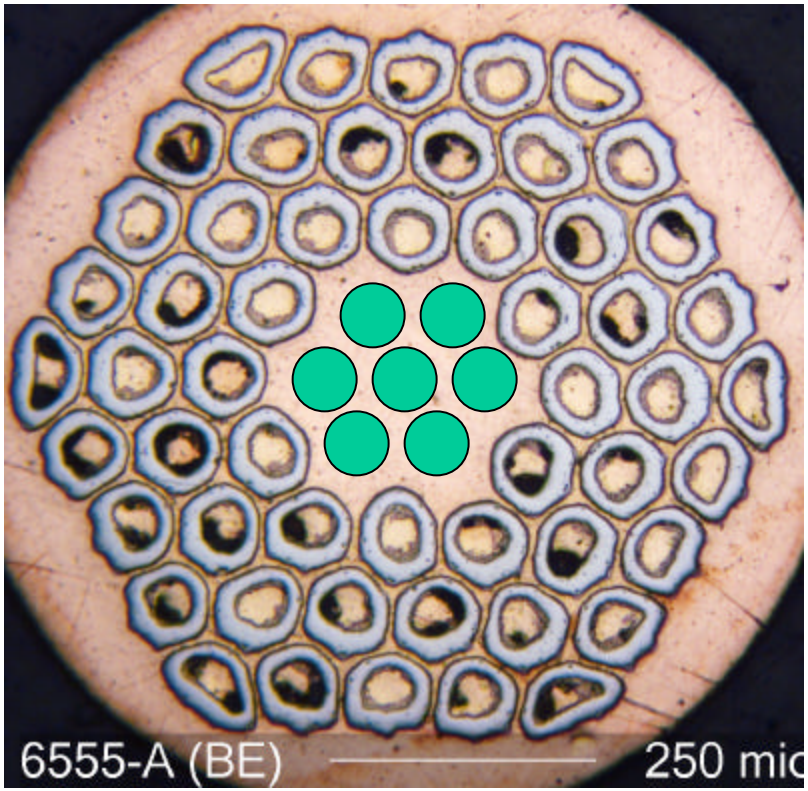
Billet	Type	Stack	Diameter (mm)	Weight (kg)		Magnet
7419	RRP	54/61	0.8	**34**	$	HD-2
7424	RRP	54/61	0.8	**36.4**	$	HD-2
7776	RRP	60/61	0.7	**2**	$	
7904	RRP	126/127	0.7	**12.1**	R&D	SQ-02
7904	RRP	126/127	0.6	**9.1**	R&D	
7933	RRP	60/61	0.7	**25.7**	$	TQ, SQ-02
7946	RRP	60/61	0.7	**22.7**	$	TQ, SQ-02
7981	HER	37/37	0.8	**9.7**	R&D	Models
7981	HER	37/37	1.615	**20.5**	R&D	Models
8079	RRP	90/91	0.7	**21**	R&D	TQ, SQ-02

TQ1a

+12kg

Conductor Properties

Billet	Type	Stack Type	Jc (12, 4.2K)	Wire Diameter (mm)	non-Cu (%)	RRR	Twist	HT	Note
7419	RRP	54/61	2894	0.8	51.9	18	12	210C/48h+400C/48h+675C/100h	
7419	RRP	54/61	3016	0.8	51.8	17	12	210C/48h+400C/48h+675C/100h	
7424	RRP	54/61	2958	0.8	50.4	16	13	210C/48h+400C/48h+675C/100h	
7424	RRP	54/61	2836	0.8	50.7	15	13	210C/48h+400C/48h+675C/100h	
7776	RRP	60/61	2904	0.7	57.8	122	?	210C/48h+400C/48h+**665C/50h**	
7776	RRP	60/61	2963	0.7	57.8	139	?	210C/48h+400C/48h+**665C/50h**	
7904	RRP	126/127	2079	0.591	59	17	?	210C/48h+400C/48h+**650C/40h**	
7904-2	RRP	126/127	1907	0.591	59	39	?	210C/48h+400C/48h+**635C/40h**	
7904	RRP	126/127	2408	0.7	59	4	?	210C/48h+400C/48h+**675C/40h**	Quench
7904	RRP	126/127	1977	1	59	19	?	210C/48h+400C/48h+**675C/40h**	
7933	RRP	60/61	2362	0.7	59	?	?	210C/48h+400C/48h+570/36+690C/50h	
7933	RRP	60/61	2325	0.7	59	?	?	210C/48h+400C/48h+570/36+690C/50h	
7946	RRP	60/61	2076	0.7	59	130	?	210C/48h+400C/48h+650C/**50h**	Low-n
7946	RRP	6061	2140	0.7	59	21	?	210C/48h+400C/48h+650C/**75h**	Higher-n
7981	HER	37/37	1972	0.8	49.7	95	?	210C/48h+400C/48h+675C/**200h**	
7981	HER	37/37	1897	0.8	49.7	165	?	210C/48h+400C/48h+675C/100h	
8079	RRP	90/91	2339	0.7	59	280	?	210C/48h+400C/48h+**635C**/40h	
8079	RRP	90/91	2427	0.7	59	34	?	210C/48h+400C/48h+**675C**/100h	

Oxford Wire Types and Sub-element Number

- Sub-element number in each ring of elements
  - 1, 6, 12, 18, 24, 30, 36
  - 1, 7, 19, 37, **61, 91, 127**
  - HD-1 was 54/61(50% Cu)
  - New R&D
    - 60/61 (40%Cu)
    - 90/91 (40%Cu) TQ
    - 126/127