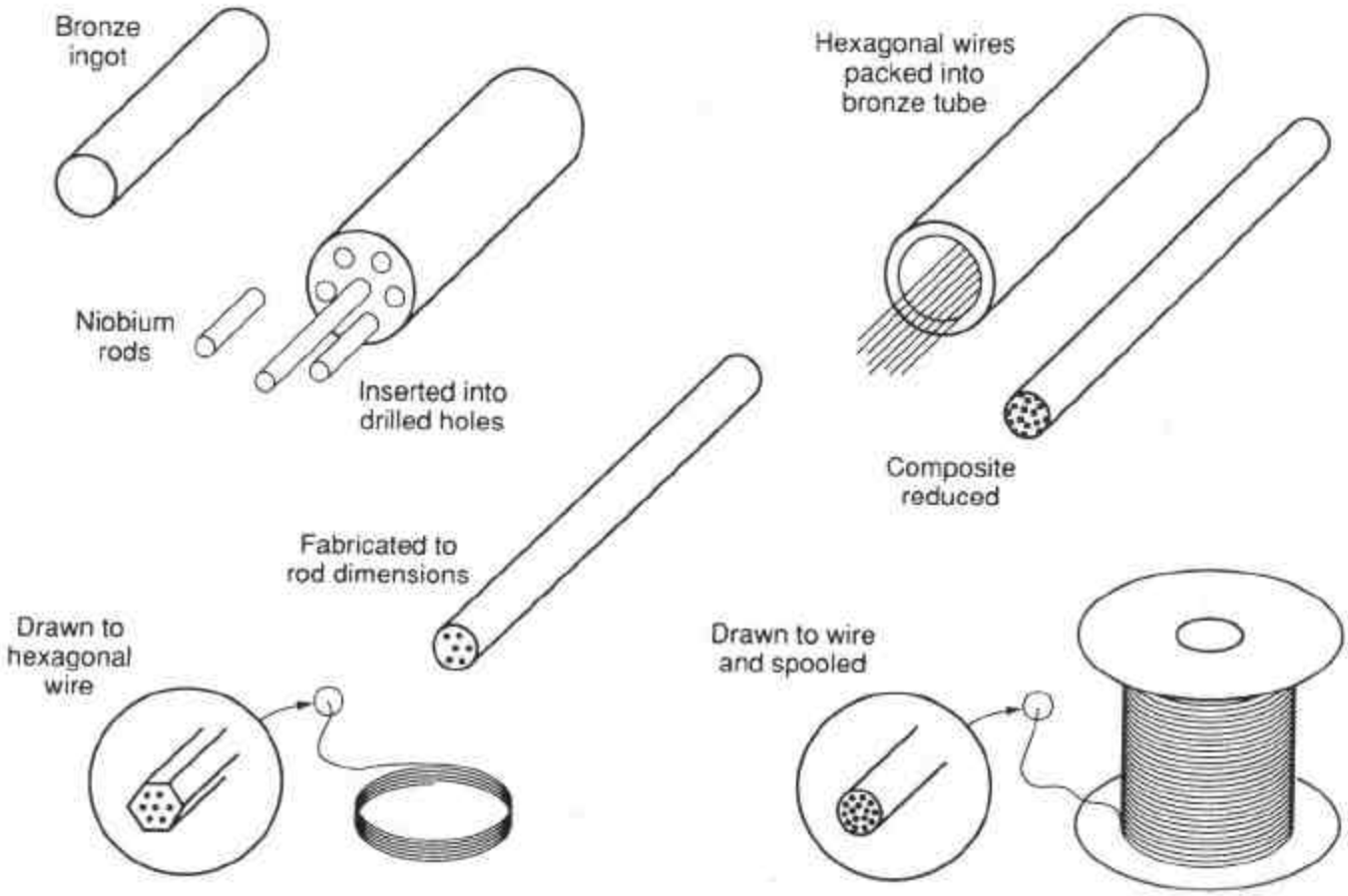
VLHC Magnet Workshop

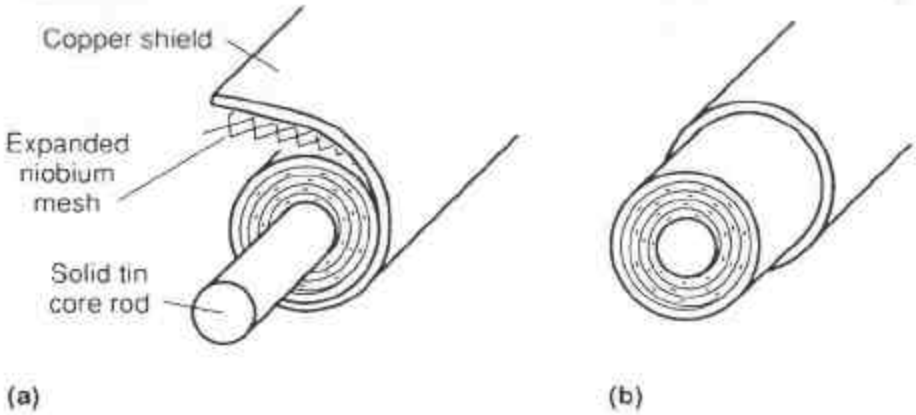
Conductor Requirements and Specifications

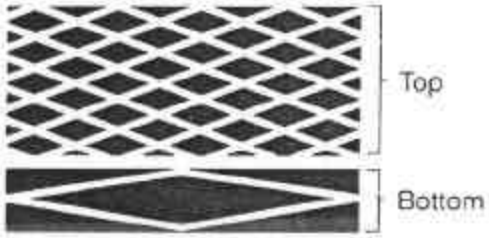
R.M.Scanlan Nov. 17, 1998

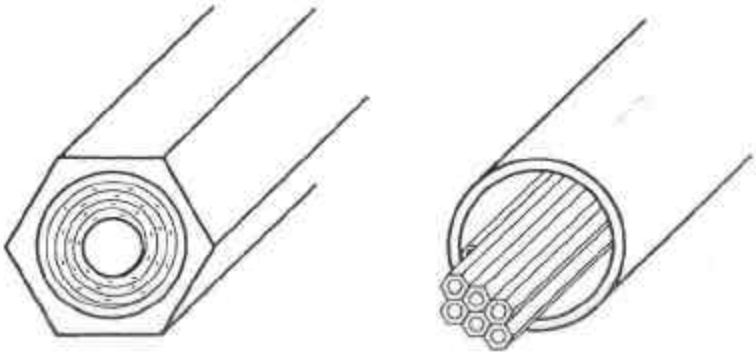
Bronze Process

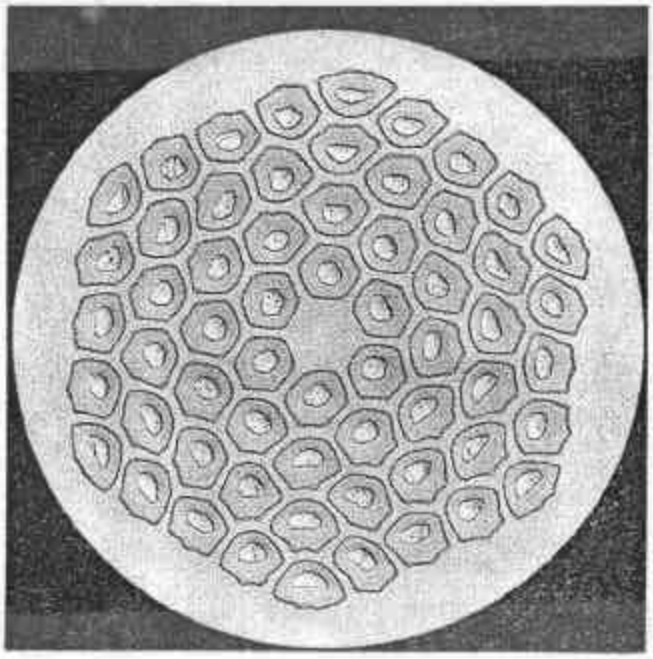


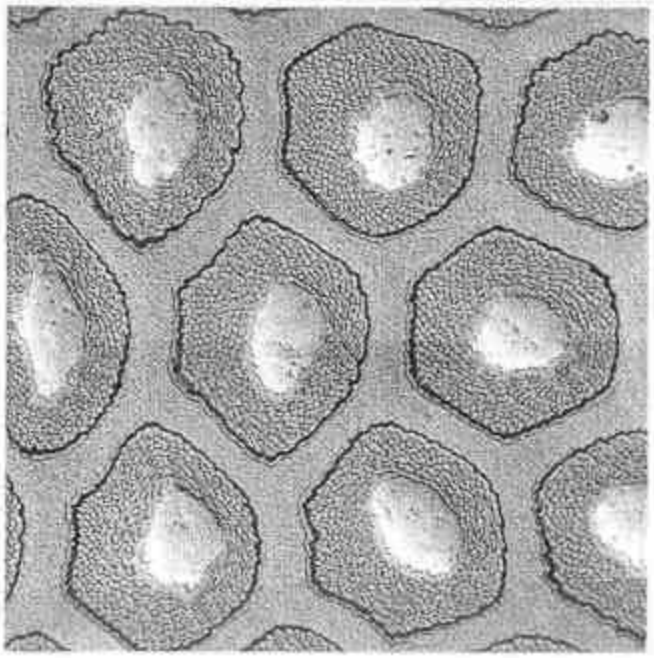
Modified Jelly Roll Process



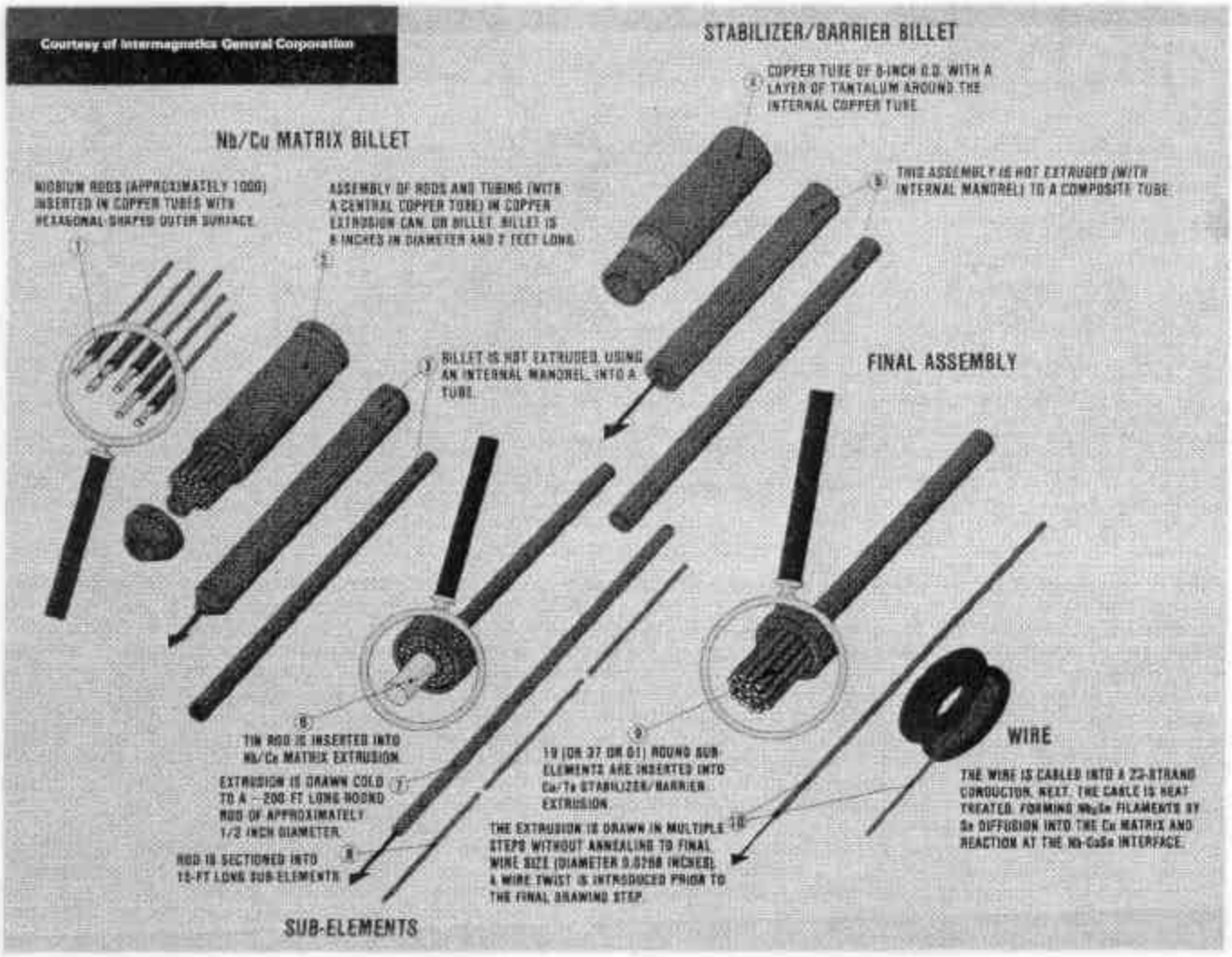








Internal Tin Process



Critical Currents in Powder in Tube Nb_3Sn wires

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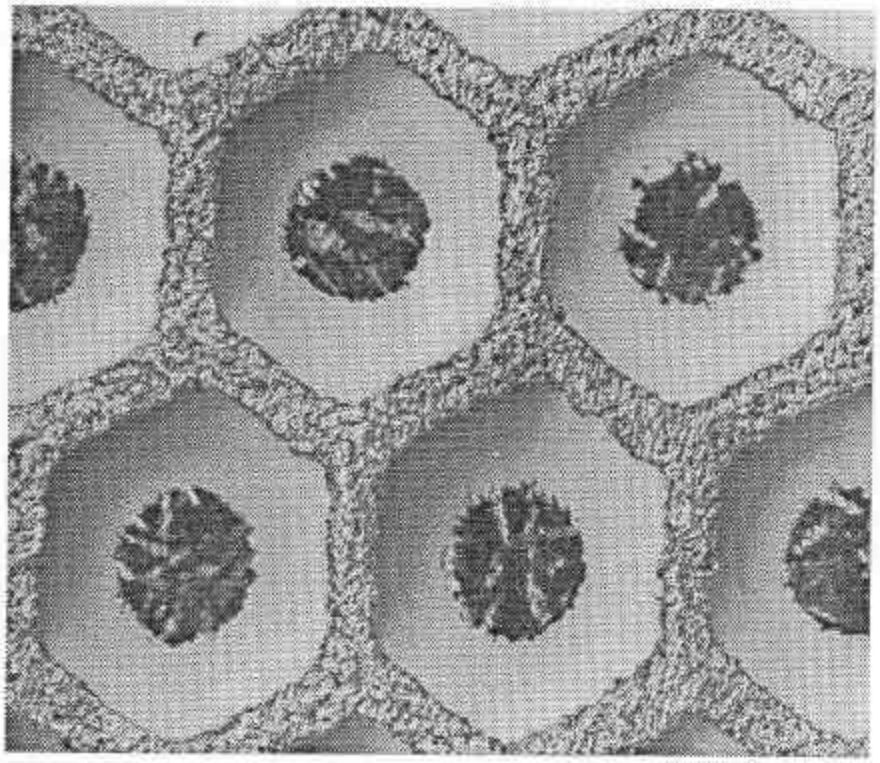


Key elements of the Conductor Specification are:

- Critical current Ic and critical current density Jc; operating field and temperature
- Magnetization or effective filament diam.
- Wire diameter
- Minimum piece length
- Copper volume fraction and RRR
- Mechanical properties

Other items to be included in the conductor specification:

- Wire twist--amount and direction
- Quality control plan
- Critical current and magnetization test method
- Heat treatment schedule
- Delivery schedule
- Shipping instructions, etc.

Target specification values for Nb_3Sn

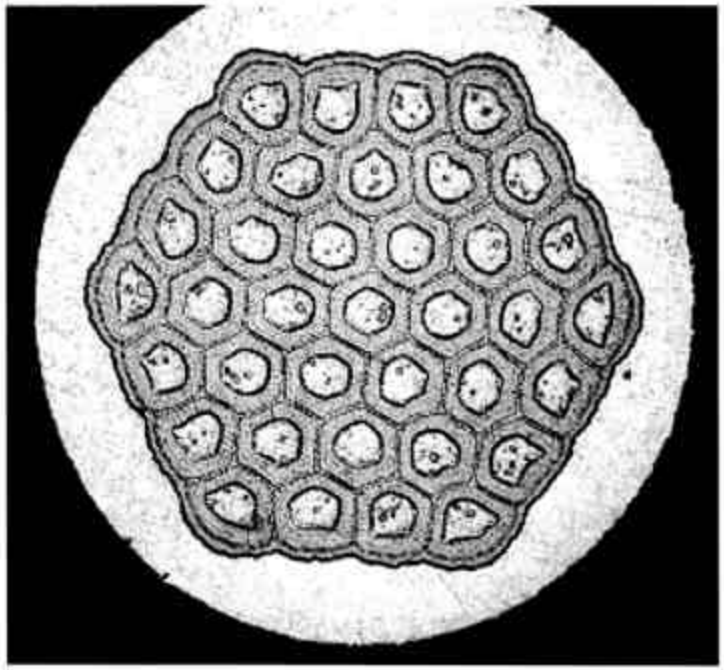
Critical current density (12T, 4.2 K)	2000 A/mm^2
D_{eff} (Interim value for intrinsic stability)	less than 20 microns (less than 80 microns)
Wire diameter	0.8 mm LBNL 1.0 mm FNAL 1.3 mm TAMU
Minimum piece length (Interim value for model magnets)	6000m (150 m)

Recent achievements in high Jc(12T,4.2K) Nb3Sn include:

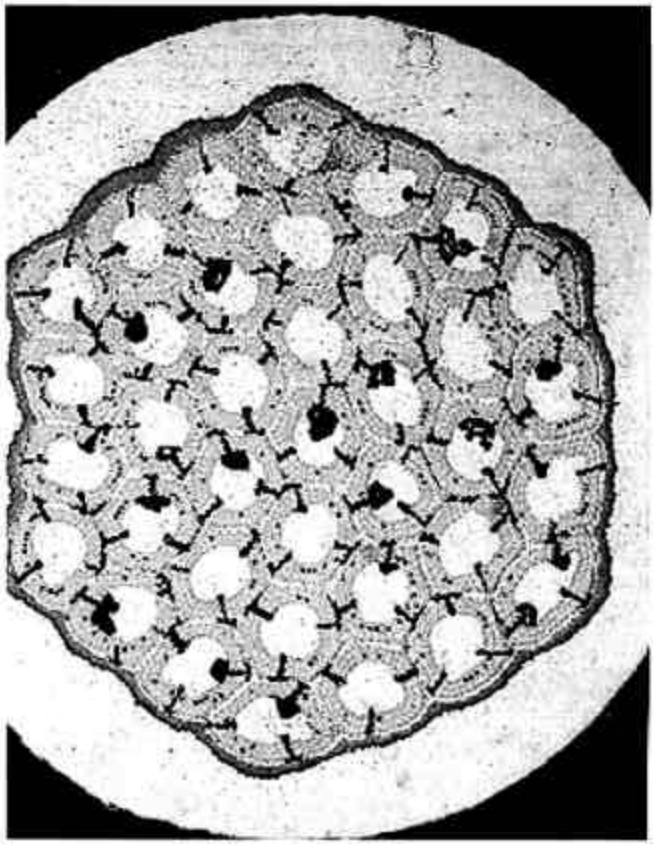
- OST/TWCA--2100 A/mm2
- IGC--2200A/mm2
- EMI--1350 A/mm2
- Mitsubishi--1285A/mm2
- SMI--1400 A/mm2
- Vacuumschmelze(bronze)--680 A/mm2

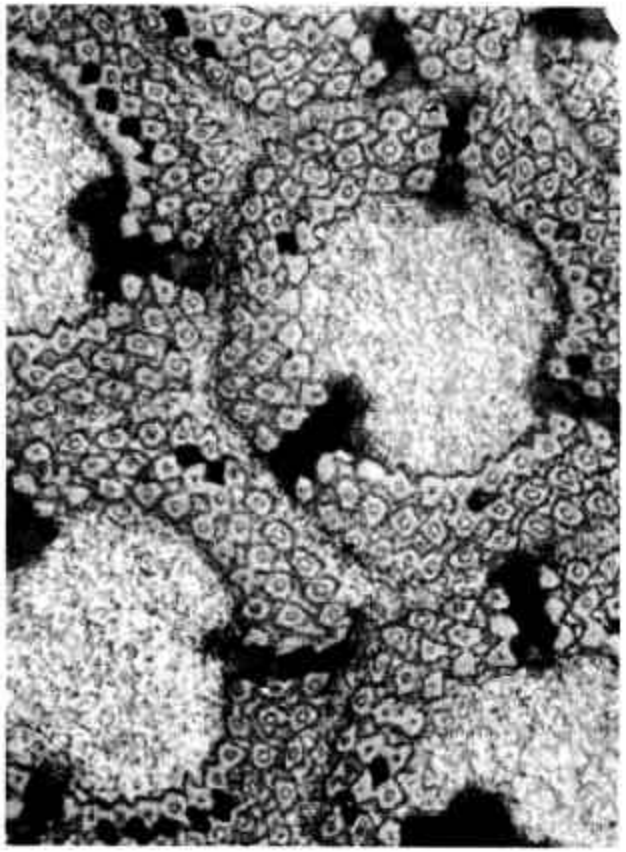
New IGC conductor for 14 T racetrack coils

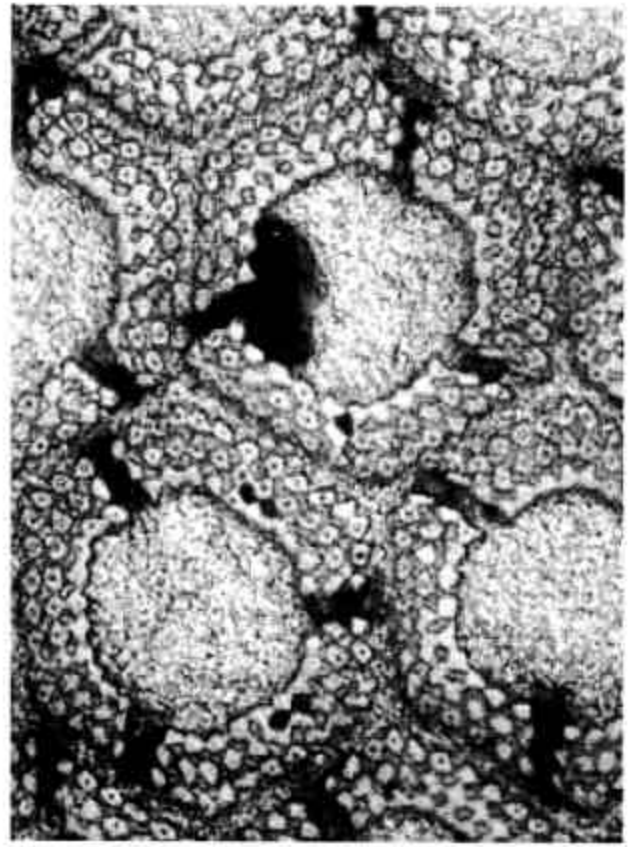
37 subelement



37 subelement split after rx







37 split 48h 61 split

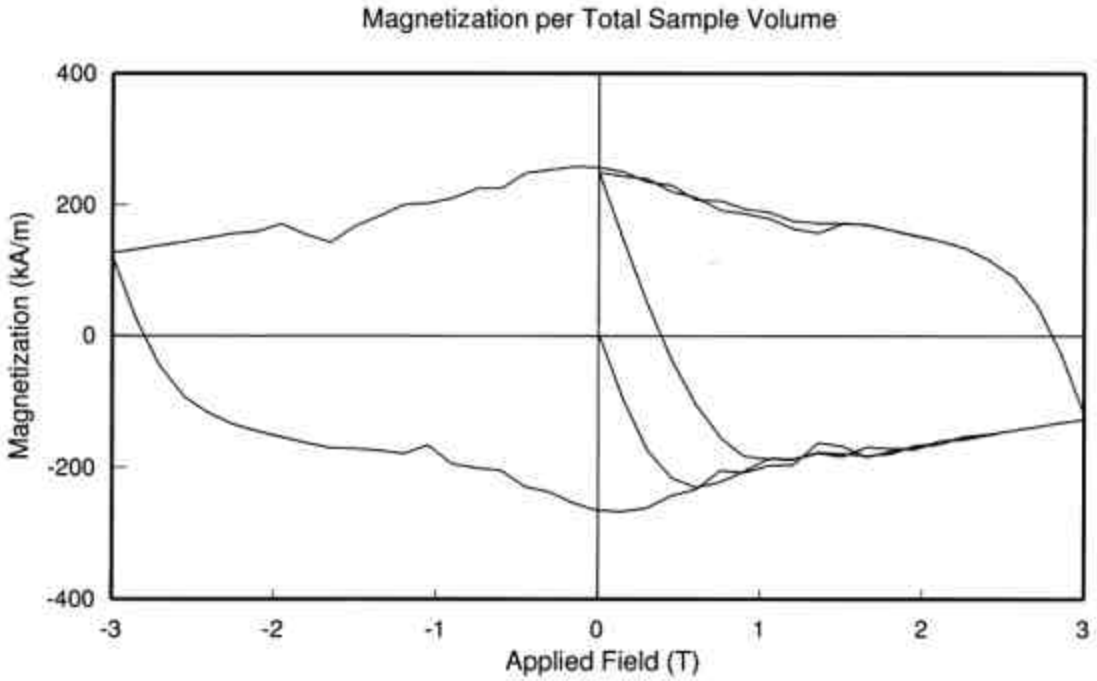
IGC ADVANCED SUPERCONDUCTORS
A DIVISION OF INTERMAGNETICS GENERAL CORPORATION

MAGNETIC CHARACTERIZATION OF SUPERCONDUCTOR STRAND

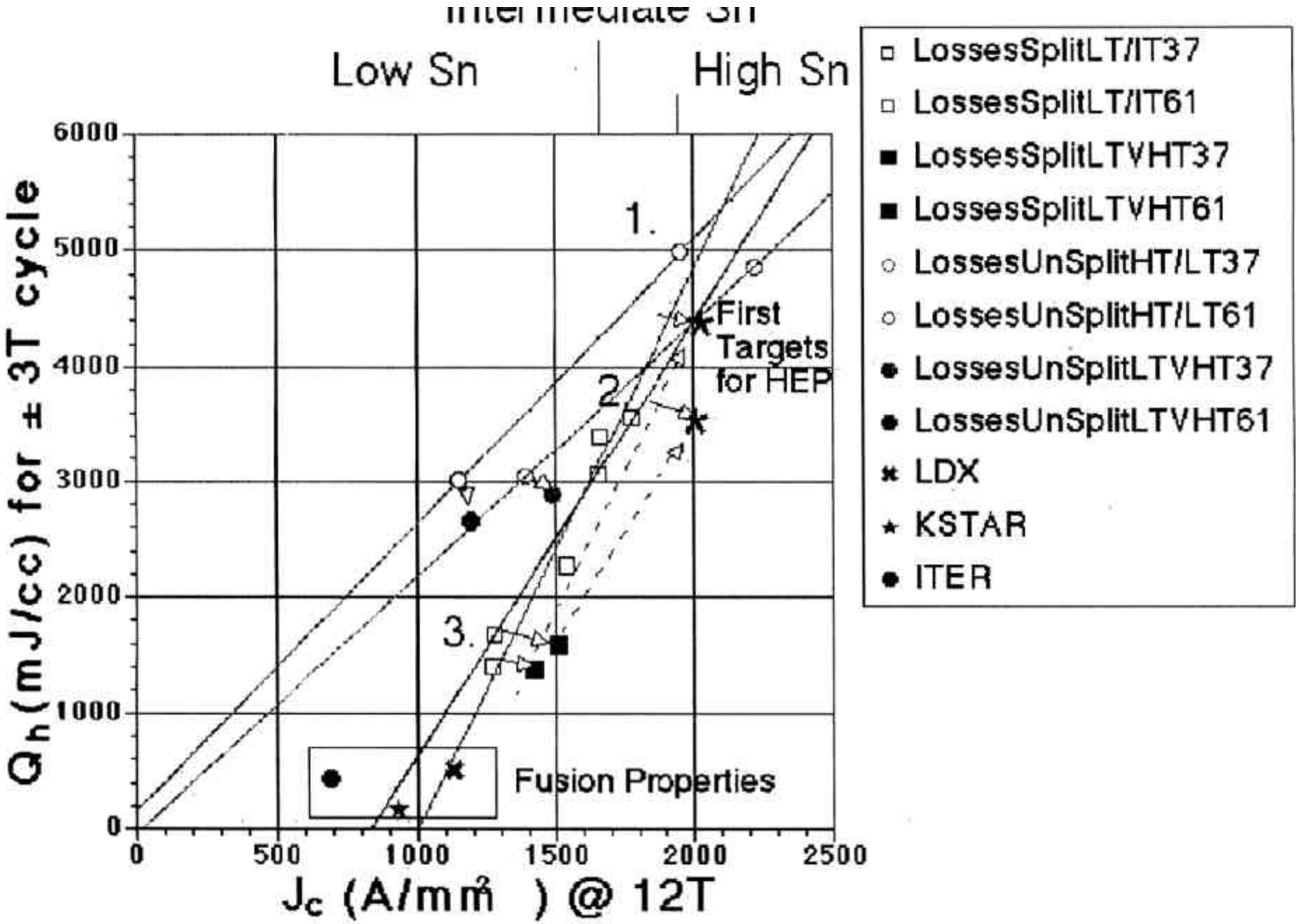
II. Sample Data (Fill Out for Each Sample)

Measurement Lab	NIST	[x] Sample Mass (g)	0.25521
Measurement Date	3 November 1998	[ ] Wire Density (g/cm³)	8.830
Sample Description	IGC SE61-436	* Volume (cm³)	0.02890
File Name	SE61-436	[ ] Fraction Non-Cu	0.601
Temperature (K)	4.22 ± 0.01	[ ] Wire Diameter (cm)	0.0517
Plated Surface / Shape	None / Coil	* Sample Length (cm)	13.77
Magnetometer/Calibration	MPM7XT/PDCAL1.MV	[ ] Twist Pitch (cm)	1.20
Calibration Coefficient	1	* Twists in Sample	11.47
TOTAL LOSS	Measured Loss (mJ)	* Loss (mJ/g)	* Loss (mJ/cm³)
Full 3T → -3T → 3T	59.11	231.63	2045.30
Pos. 3T → 0 → 3T	23.30	91.31	806.31
NON-COPPER LOSS	* Loss (mJ)	* Loss (mJ/g)	* Loss (mJ/cm³)
Full 3T → -3T → 3T	98.36	385.41	3403.16
Pos. 3T → 0 → 3T	38.78	151.94	1341.61
[ ] Jc at 3 T (GA/m²)	* Deff at 3 T (μm)	[ ] Jc at 5 T (GA/m²)	* Deff at 5 T (μm)
4.138	62.5	2.717	159.1

*=Calculated value. [x]=Quantity measured in Lab. [ ]=Value provided by manufacturer.



Standard Data Sheet, Ver. 19 May 98, R. B. Goldfarb, NIST



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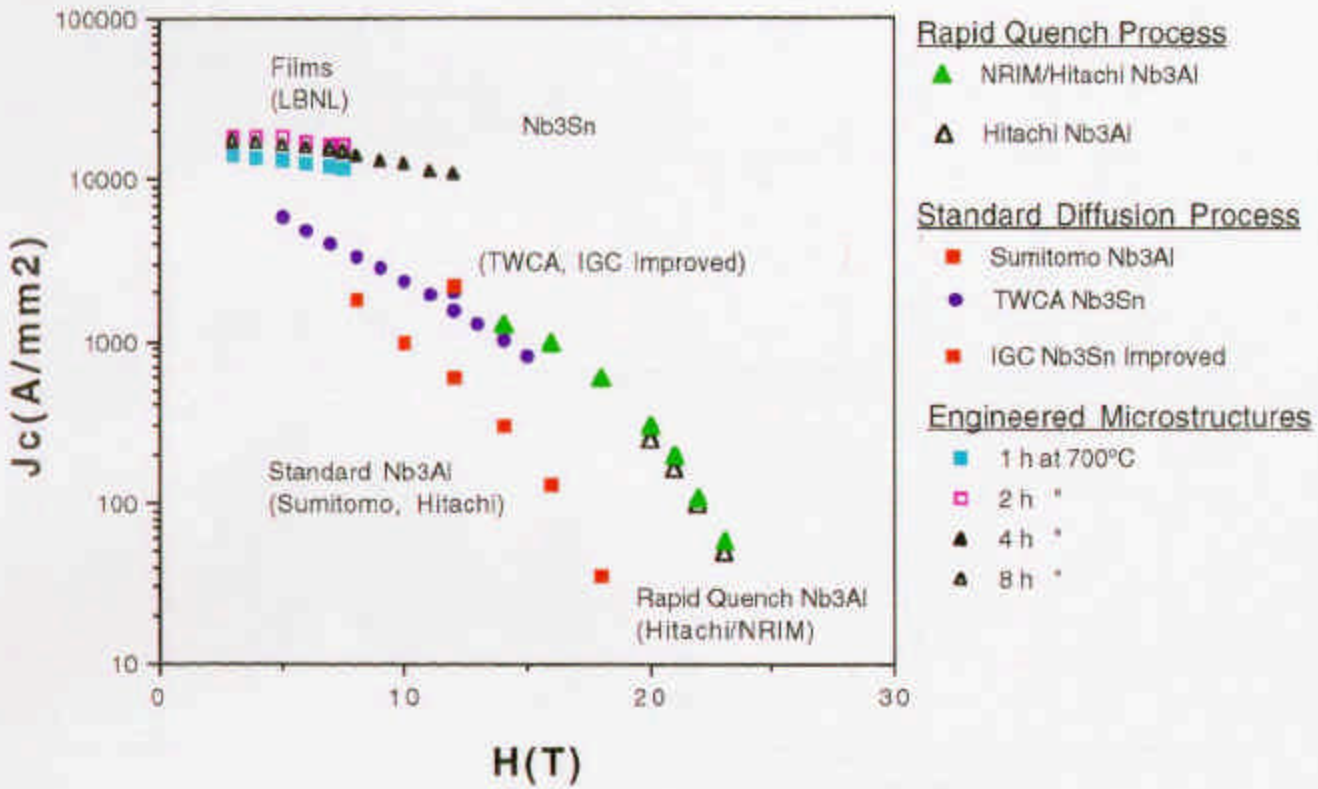
Nb3Sn Status and Proposal

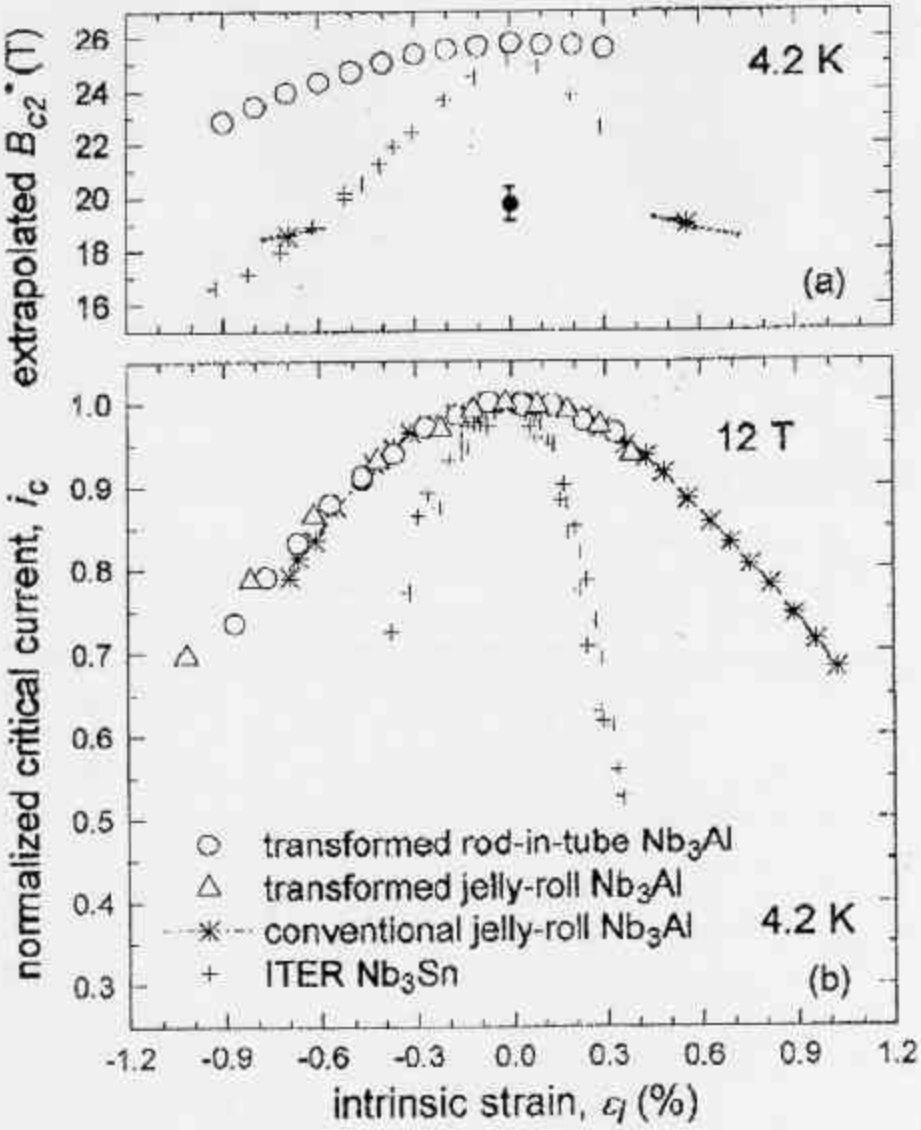
- Nb3Sn conductor enhancement/process scale-up has the strong support of three U.S. magnet development groups--LBNL, TAMU, and FNAL.
- Recent R&D results show that the potential for Jc improvements is large (a factor of 3-5). These results have stimulated work on three SBIR Phase I proposals.
- The cost reduction potential for Nb_3Sn is huge. Present cost is dictated by small process unit size and limited demand.
- Both IGC and OST have expressed ideas and interest in Jc improvement and process scale-up work.
- Significant progress can be made with a focussed effort on large size billet fabrication. This will provide for scale-up from the 12 kg batch size at present to a 150-200 kg batch size. Some of the material from this effort can be used in the magnet programs at LBNL, TAMU, and FNAL.

Critical Current of LTS Conductor



To be published in Applied Physics Letters

TAKEUCHI ET.AL. NRIM
TEN HAKEN ET.AL. U. TWENTE



Nb3Al Status

- Substantial Japanese effort on this conductor, supported by JAERI, NRIM, and KEK and involving Japanese industry (Sumitomo and Hitachi)
- No support in the U.S. outside HEP and the HEP SBIR topics
- We have a good start with the OSU, LBNL, IGC, OST collaboration
- FY 99 Phase I SBIR's will help sustain momentum, and will be a significant source of support if they are converted into Phase II efforts. One Phase II is funded at present(Plastronics/OSU/IGC)
- Establishing the feasibility of the rapid quench process is the highest priority. Conventional process Nb3Al does not offer significant benefits over Nb3Sn.
- Some additional funding for precursor material to use in rapid quenching process development will be useful in order to supplement SBIR work.

Cable fabrication from Bi-2212 strands—what we have learned:

- Fabrication of Rutherford type cables from Bi-2212 wires can be done reliably, and with acceptably low Ic degradation.
- The present generation wire requires the use of a core in order to reduce the bending radius of the strands in the cable.
- Both thick (1mm) and thin (0.4 mm) cores are promising for 0.8 mm diameter strands. The thicker core is preferred for cables made from pre-aspected stands.
- Nichrome has been used with success as a core material (compatible with Bi-2212 strands and readily available). There may be other acceptable materials as well.
- We have observed a tendency for wire breaks during cabling to increase as the matrix:BSCCO ratio is reduced from 3:1 to 2:1.
- With present generation wire, we have achieved cable Ic's at 4.2 K of greater than 1000 A at 5 T in an 18 strand cable.
- New result—1600 A at 4 T.
- AC loss measurements show good interstrand resistance values in cored HTS cables

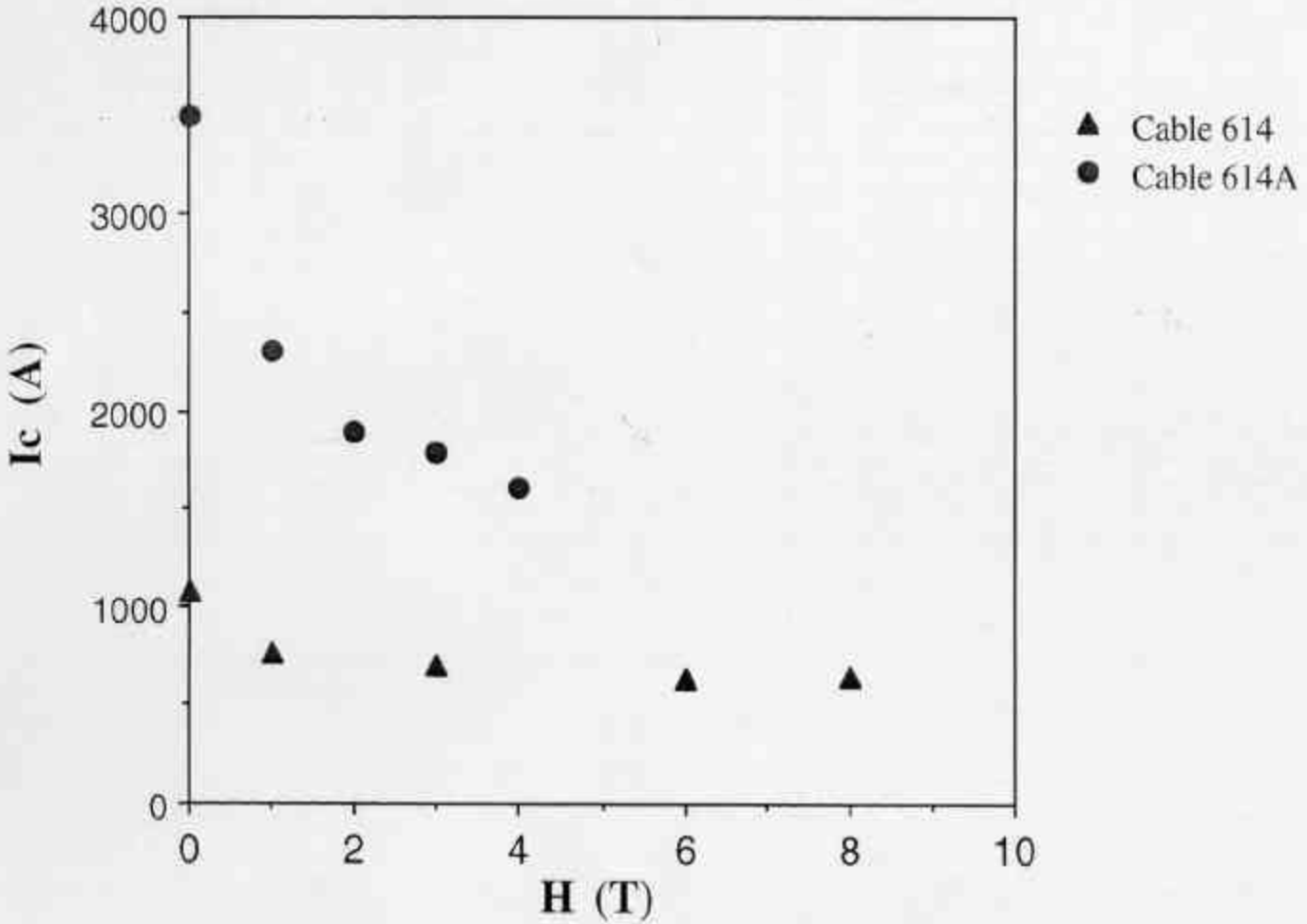
CABLES MADE FROM IGC WIRES

Cable #	Strand I.D.	Strand #	Core Mat'l Thick. (mm)	Ic(A)@ T (4.2 K)
613	SN 380	18	Nichrome 0.390	1080@0T 650@8T
614	SN 380	19	Nichrome 0.390	2100@0T
614A	SN 380	19	Nichrome/ MgO tape 1.092	3400@0T 1650@4T
640	SN 410	19	Nichrome/ MgO tape	
641	SN 430	19	Nichrome/ MgO tape	

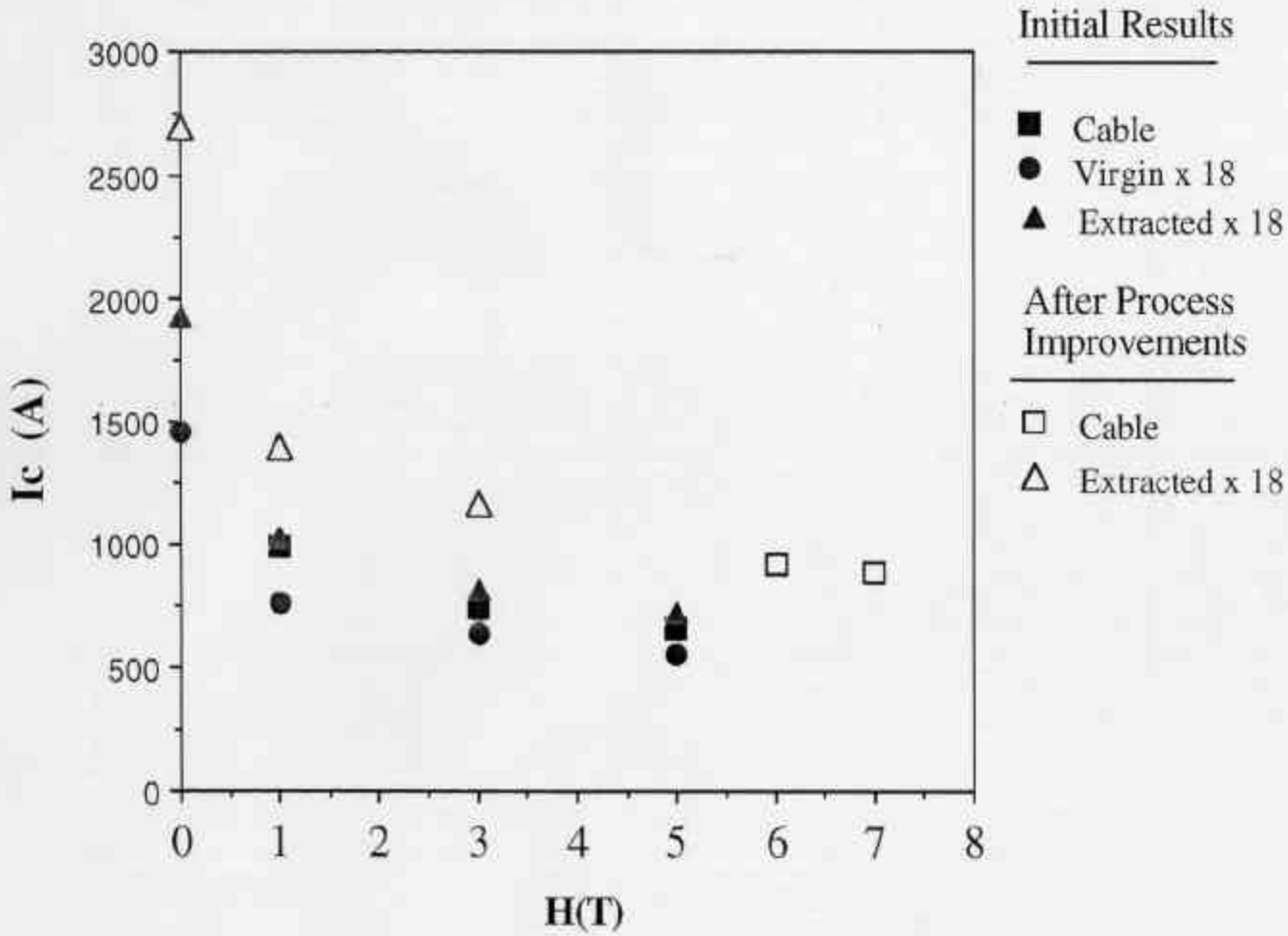
CABLES MADE FROM OST WIRES

Cable No.	Strand I.D.	Strand No.	Core Mat'l Thick. (mm)	Ic(A)@ 6T (4.2 K)	Remarks
607	PM040997	19	Nichrome 1.092	950	
608	PM040997	18	Nichrome 0.392	920	
643	PM041797	19	Nichrome 1.092		Strand annealed

Cable Made From IGC Wire



Cable Made From OST Wire



Conclusions

A number of challenges have been met and overcome during this program aimed at developing HTS cables for accelerator magnet applications.

- Wire Ic values have been increased by over a factor of 2
- Cable degradation and ac losses have been minimized by use of a core
- Contamination has been reduced by coating the core with MgO
- The best cables have Ic values exceeding 1650 A (670 A/mm^2) at 4.2 K and 5.0 T

What's New in Bi-2212 and 2223?

- Ductility required for long length cables was achieved by intermediate annealing of strands
- Matrix:SC ratio can be reduced to produce a more cost effective conductor
- Processing unit size is being scaled up from 5 Kg to 25 Kg
- Jc improved via process changes to 3600 A/mm2, 10 T and 4.2 K(NRIM)
- Strain behavior looks more promising for Bi-2223 and Bi-2212

FY 99 HTS Conductor development plan

- Measure Jc vs strain for Bi-2212 cables (LBNL)
- Scaleup process unit size (IGC and OST)
- Optimize heat treatment/insulation for wind and react process (LBNL, U.Wisc, OSU, IGC, OST)
- Evaluate react and wind process for Bi-2212 cables (LBNL)
- Wind racetrack coils from Bi-2212 cables (LBNL)

The Bi-2212 effort has made significant progress as an informal collaboration with a small amount of direct funding. The informal collaboration will be O.K. for this next step, but the effort needs some additional direct funding. Especially for the costly scaleup work and for the university groups that have no direct Bi-2212 funding (Hellstrom and Collings).