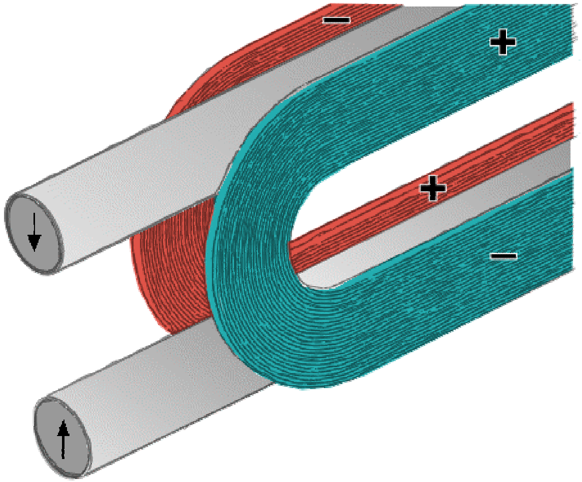

Test Results on HTS Coils for Common Coil Magnets

M. Anerella
J. Cozzolino
J. Escallier
G. Ganetis
A. Ghosh
R. Gupta

M. Harrison
G. Morgan
J. Muratore
B. Parker
W. Sampson
P. Wanderer

Arup Ghosh and Ramesh Gupta
Superconducting Magnet Division
Brookhaven National Laboratory
Upton, NY 11973 USA

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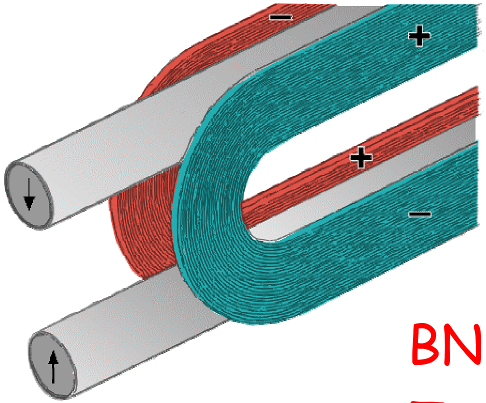
Superconducting Magnet Division

HTS Common Coil Magnet Program at BNL

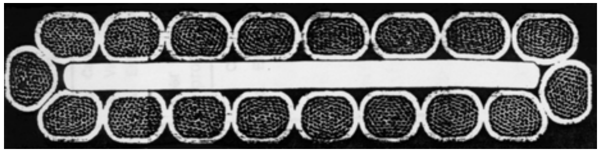


HTS is brittle. Common coil design was developed to overcome that limitation.

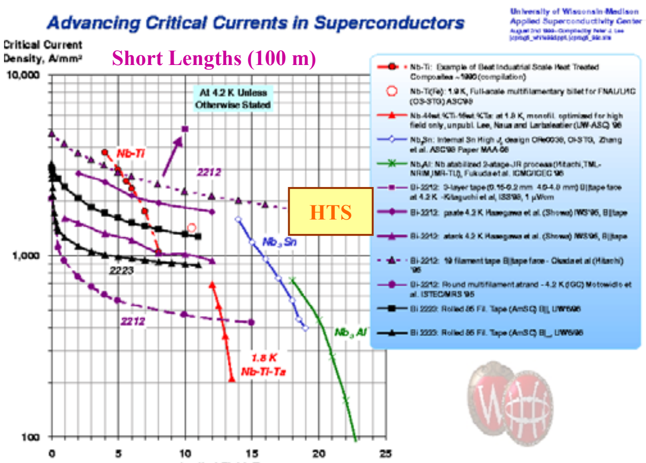
Bill Sampson has been working on common coil magnets with HTS tapes for ~2 years.

BNL has now also started a HTS cable magnet program.

Two 10-turn coils have been made and extensively tested.

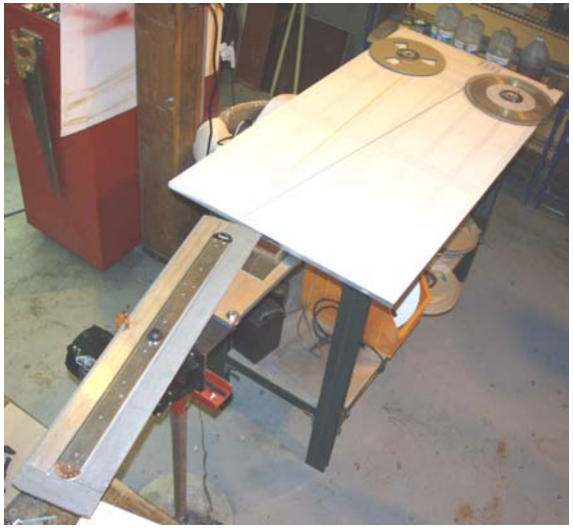


A good and productive collaboration has been established between labs (BNL, LBL) and industries (IGC, Showa).



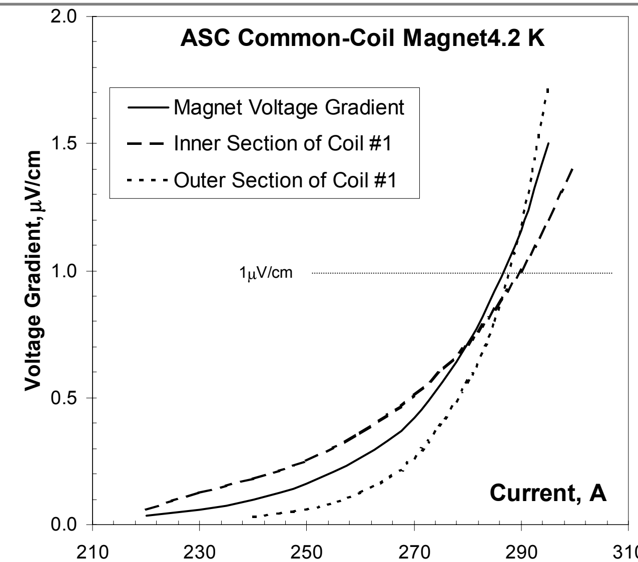
Recently tested BSCCO 2212 wire at Showa/IGC has current density comparable to Nb_3Sn at high fields (15-20 T).

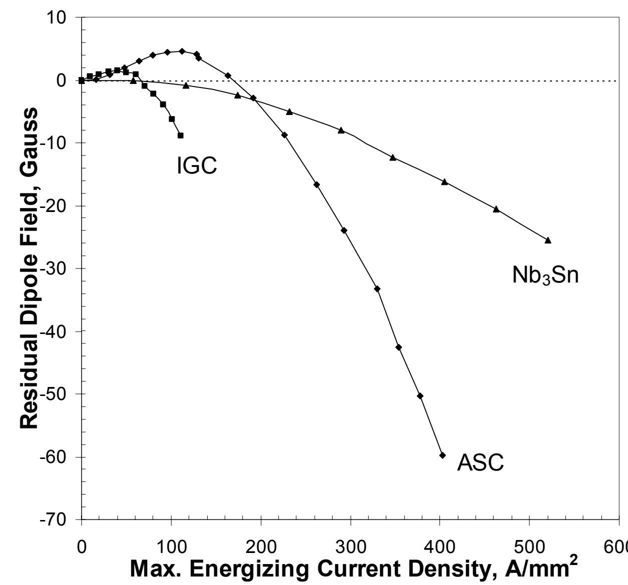
Common Coil Magnets With HTS Tape



A coil being wound with HTS tape and insulation.

Two HTS tape coils in common coil configuration

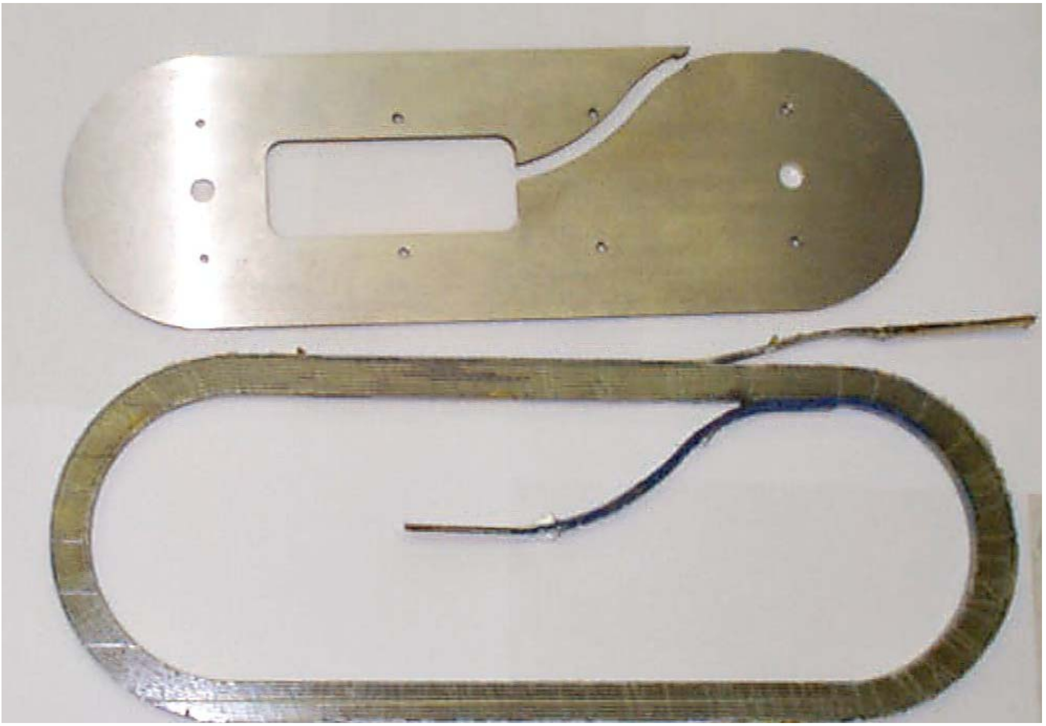




Status of HTS tape coils at BNL

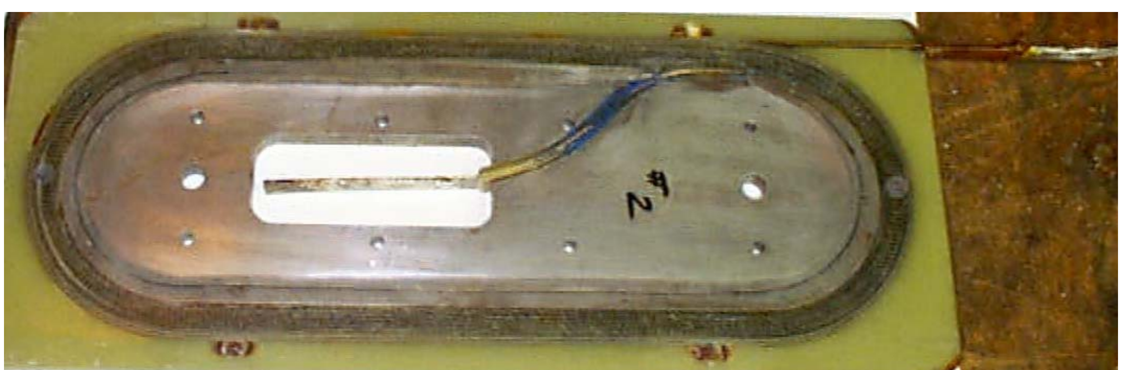
	Size, mm	Turns	Status
Nb_3Sn	0.2 x 3.2	168	Tested
IGC	0.25 x 3.3	147	Tested
ASC	0.18 x 3.1	221	Tested
NST	0.20 x 3.2	220	Under construction
VAC	0.23 x 3.4	170	Under construction

The Bobbin and the 10-turn Coil



The bobbin
(the coil is wound on it)

The first 10-turn practice coil
(removed from bobbin after impregnation)



The complete cassette module
(vacuum impregnated coil in bobbin)

HTS Coils in Support Structure

Coils are heavily instrumented. There is a voltage tap after each turn. Data were recorded from all 26 voltage taps.

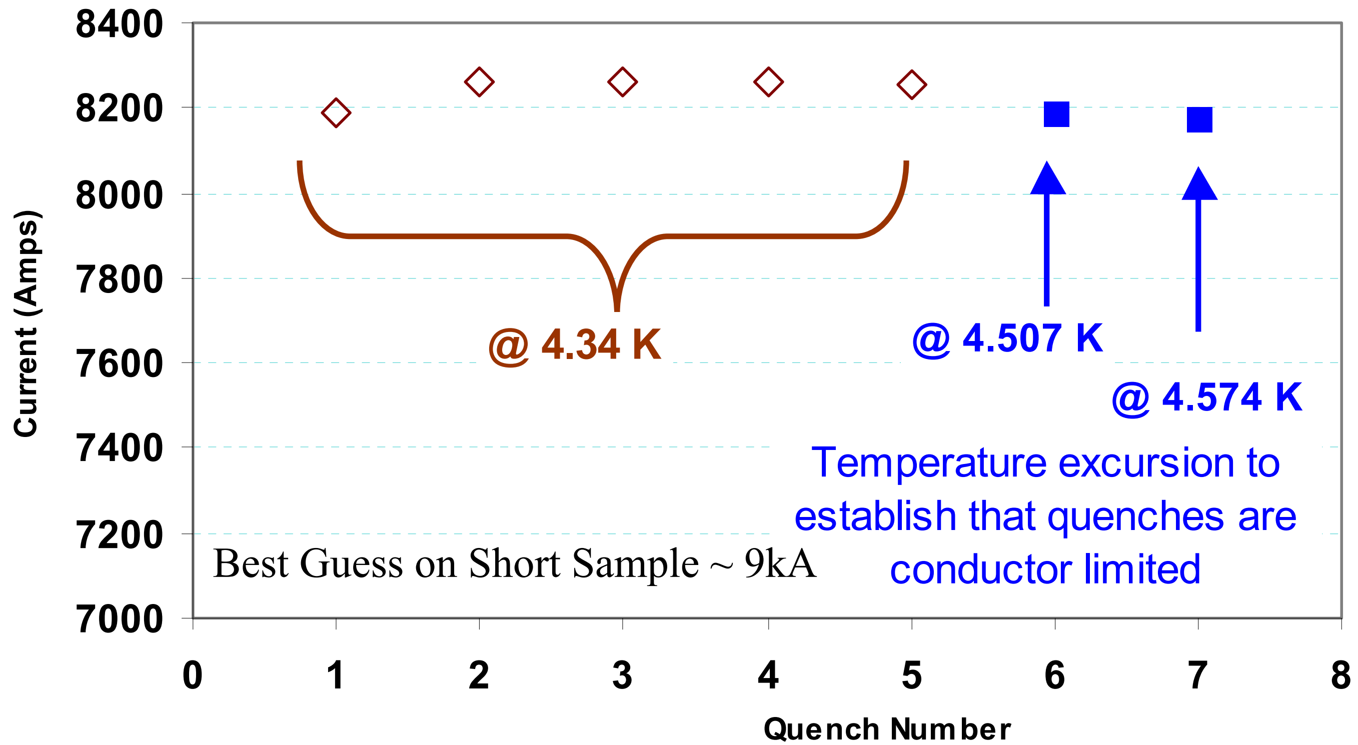
Coils are assembled for the most flexible and extensive testing. Four leads are taken out of the cryostat. During the test the coils were powered separately and together in “common coil” and “split-pair solenoid mode”.

Two hall probes (in between two coils and at the center of two coils) also recorded the central field.

First Step: Test The Design and Construction Techniques with React & Wind Nb_3Sn Coils

Test the design with Nb_3Sn coils to eliminate major design & construction flaws

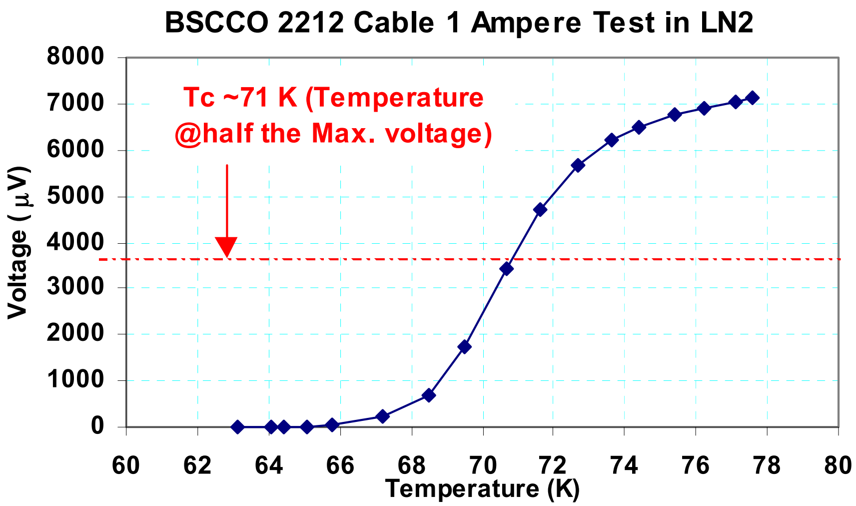
same design (common coil) and similar technology (react & wind)

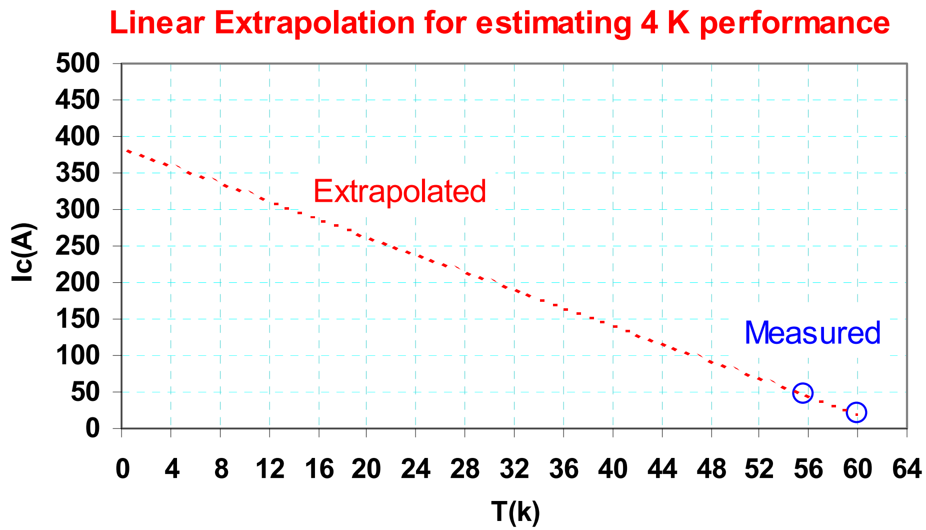


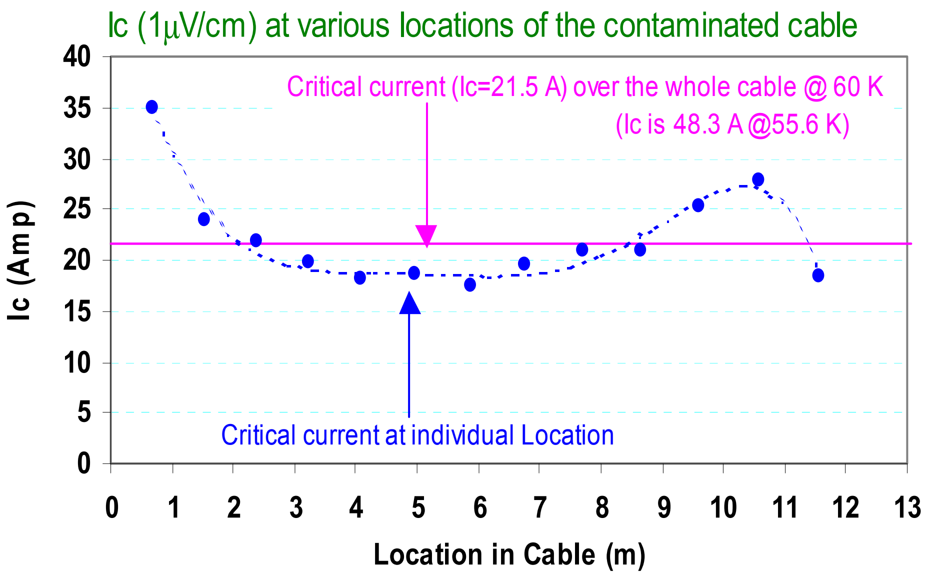
A reasonable quench performance (one training quench) and relatively small additional cable degradation in first attempt, despite brittle Nb_3Sn being subjected to high strain of NbTi coil making process, is an encouraging sign for the future of "React & Wind" common coil magnets (including scale up process).

Nb3Sn coils were wound by machine and HTS Coils were wound by hand but both have the same 70 mm bend radius.

HTS Cable Test at LN2 and Extrapolation to 4 K



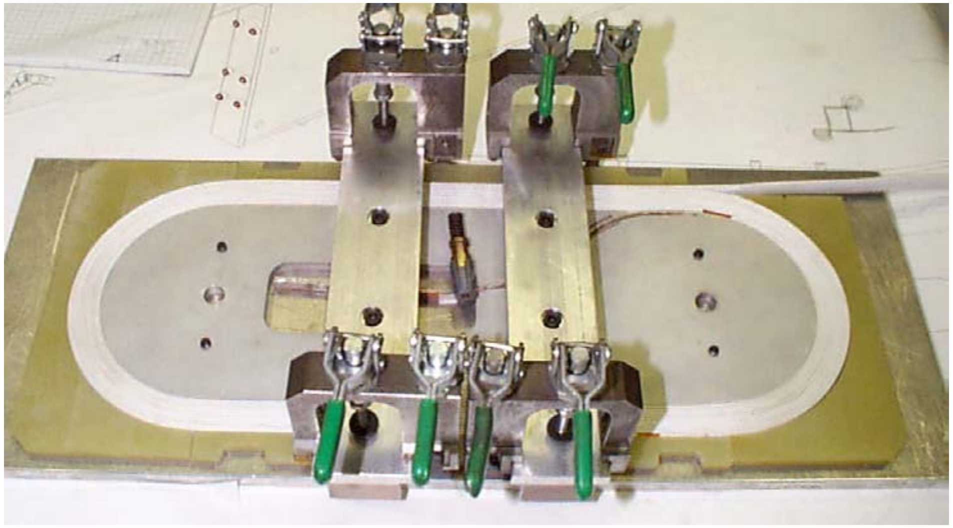




Notes:

- Measurements at LN2 give important QA information
- This cable was a reject cable; we used it to obtain initial experience in winding HTS coils
- The cable has large variation in I_c across the length
- Expected Ic at 4K ~360 A based on linear extrapolation

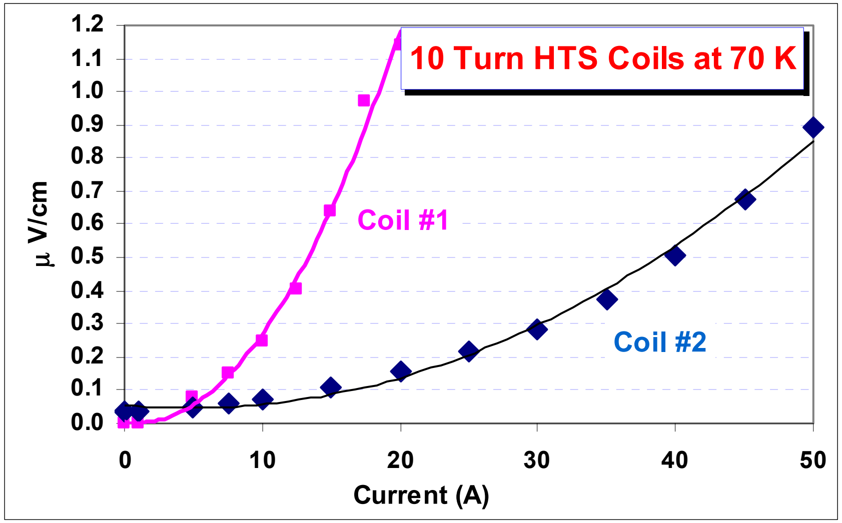
Common Coil Magnets With HTS Cable



HTS cable coil prior to vacuum impregnation

A coil cassette made with HTS cable after vacuum impregnation and instrumentation

Two coils were tested in Liquid Nitrogen



The HTS cables were from two different batches. They behaved differently:

- Different Ic
- Different Tc

Based on preliminary analysis, no large degradation was observed.

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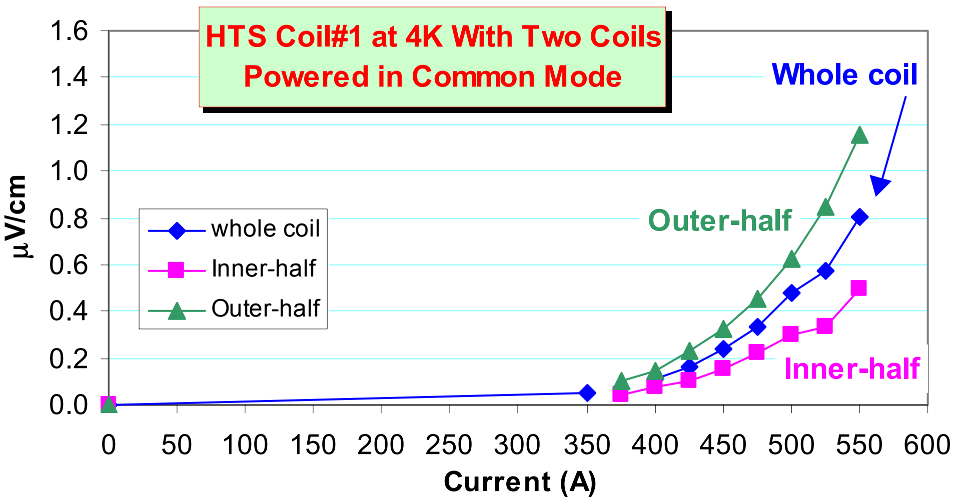
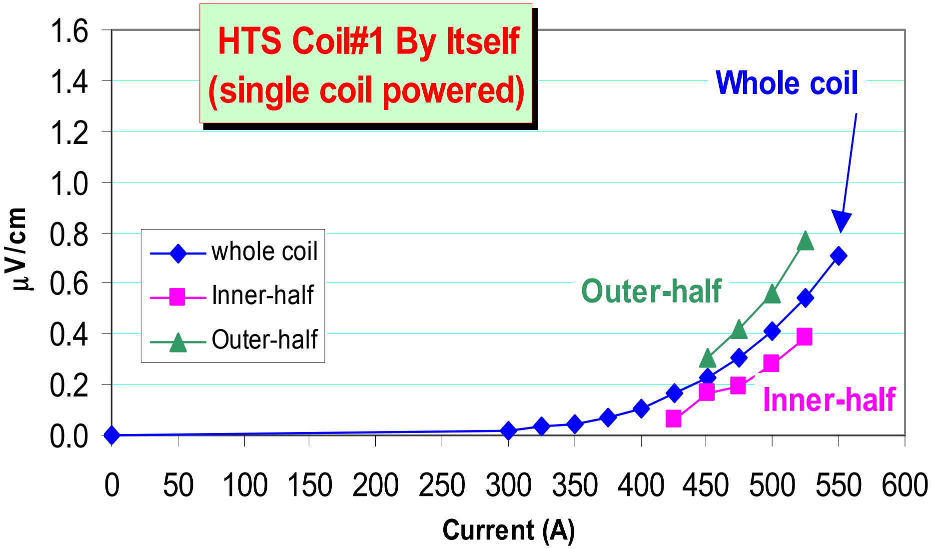
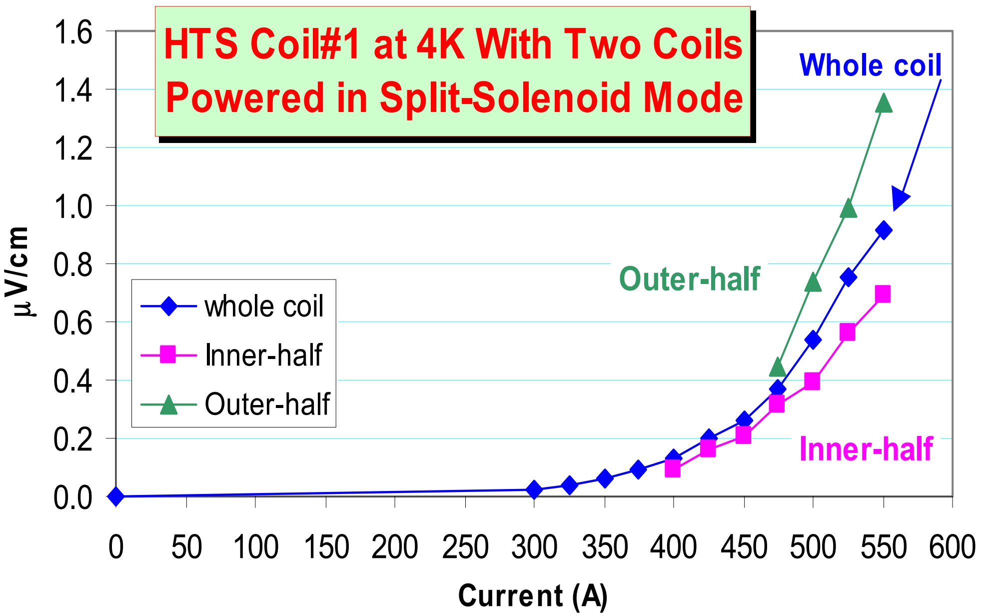
4K Performance of 1st Common Coil HTS Magnet







Notes:

- The cable in coil#2 was better than that used in coil #1; no clear onset of resistive state was observed up to 550 A. See results of next tests at higher current.
- Observed performance of coil#1 is line with expectation (no large/significant degradation was observed).
- The inner coil half (smaller bend radius) has better performance. It was made with the better part of cable - as per LN2 measurements. This means that the cable performance rather than degradation during manufacturing is determining the performance --- an encouraging result indeed.

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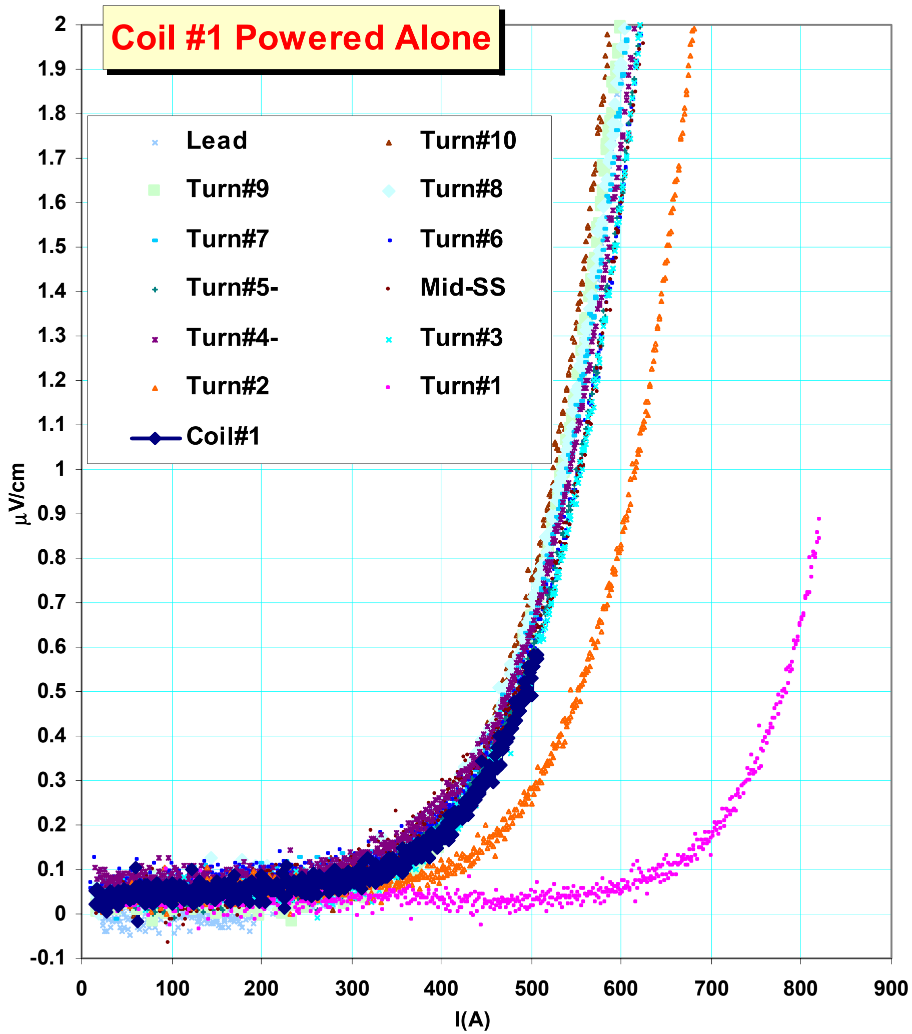
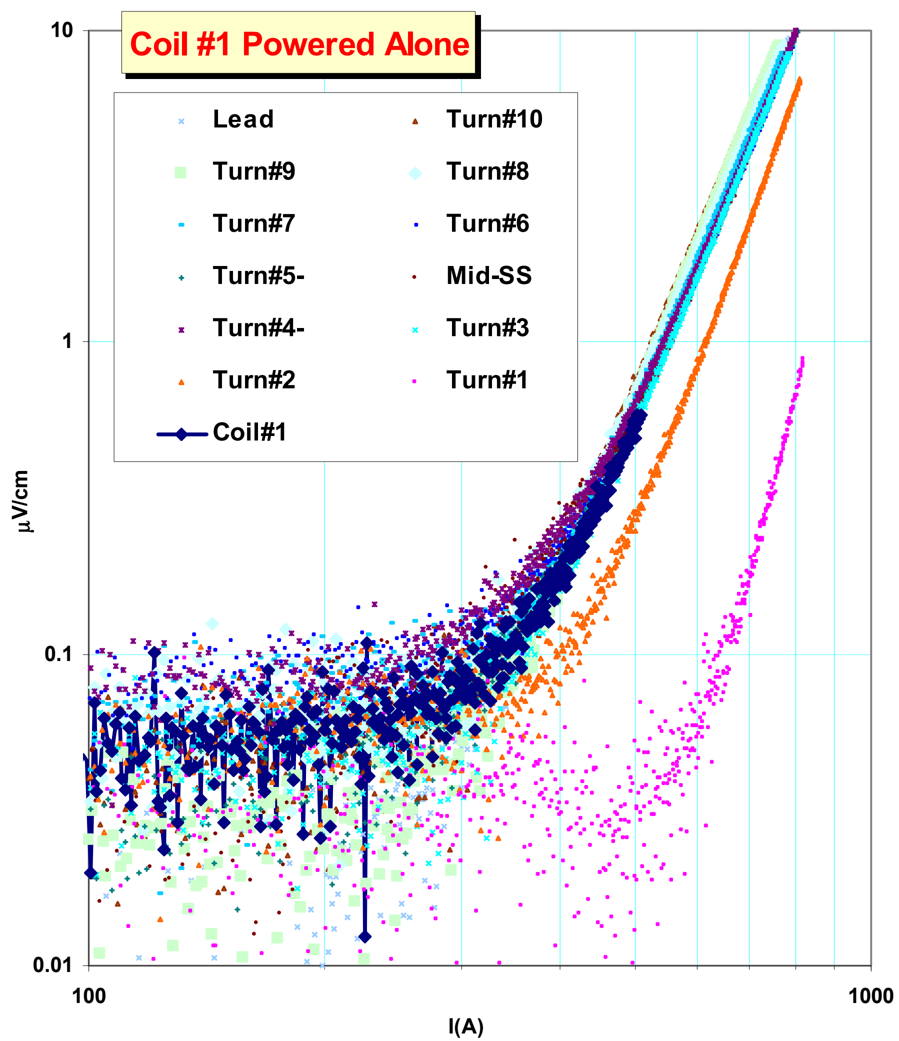
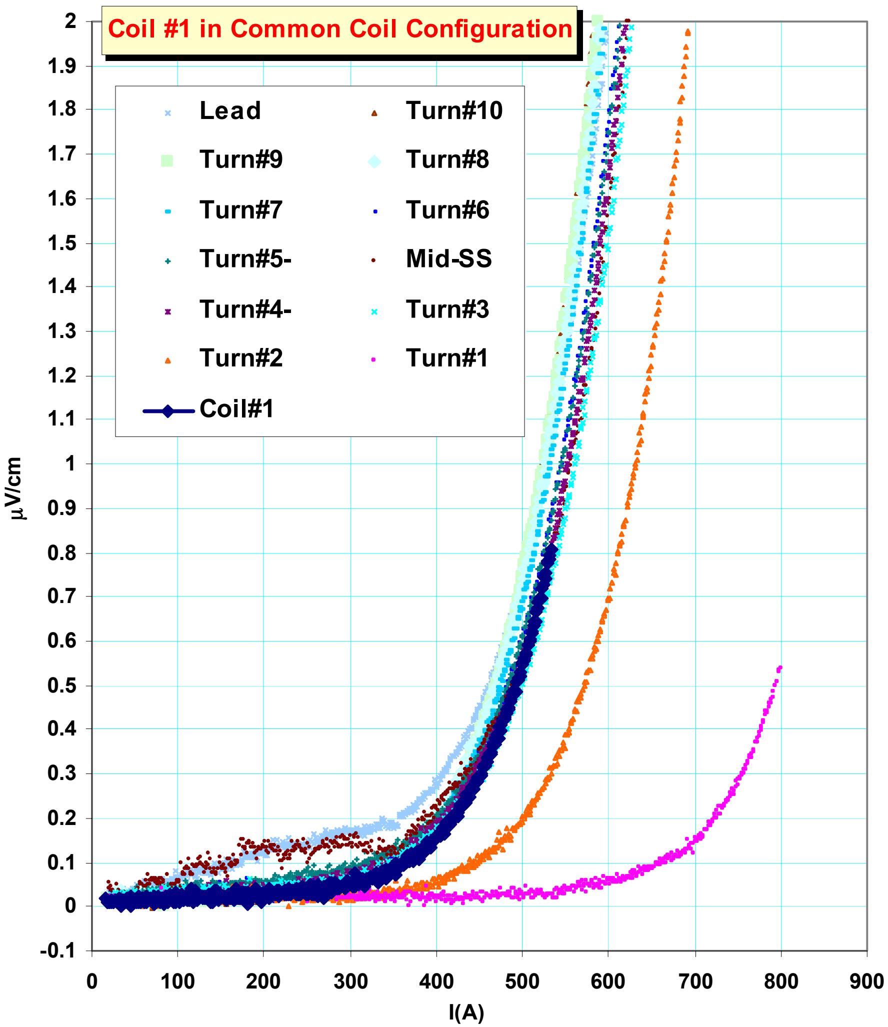
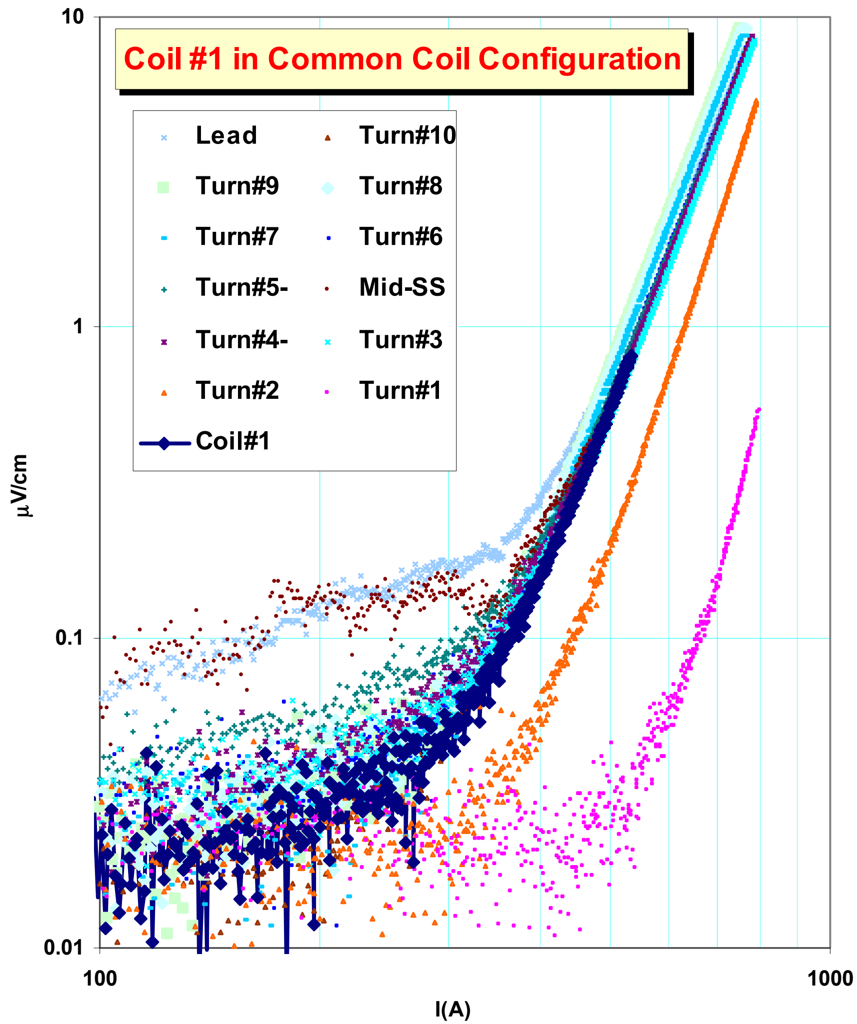
Performance of Coil #1 Powered Alone (Coil #2 off)





Performance of Coil #1 in Common Coil Configuration





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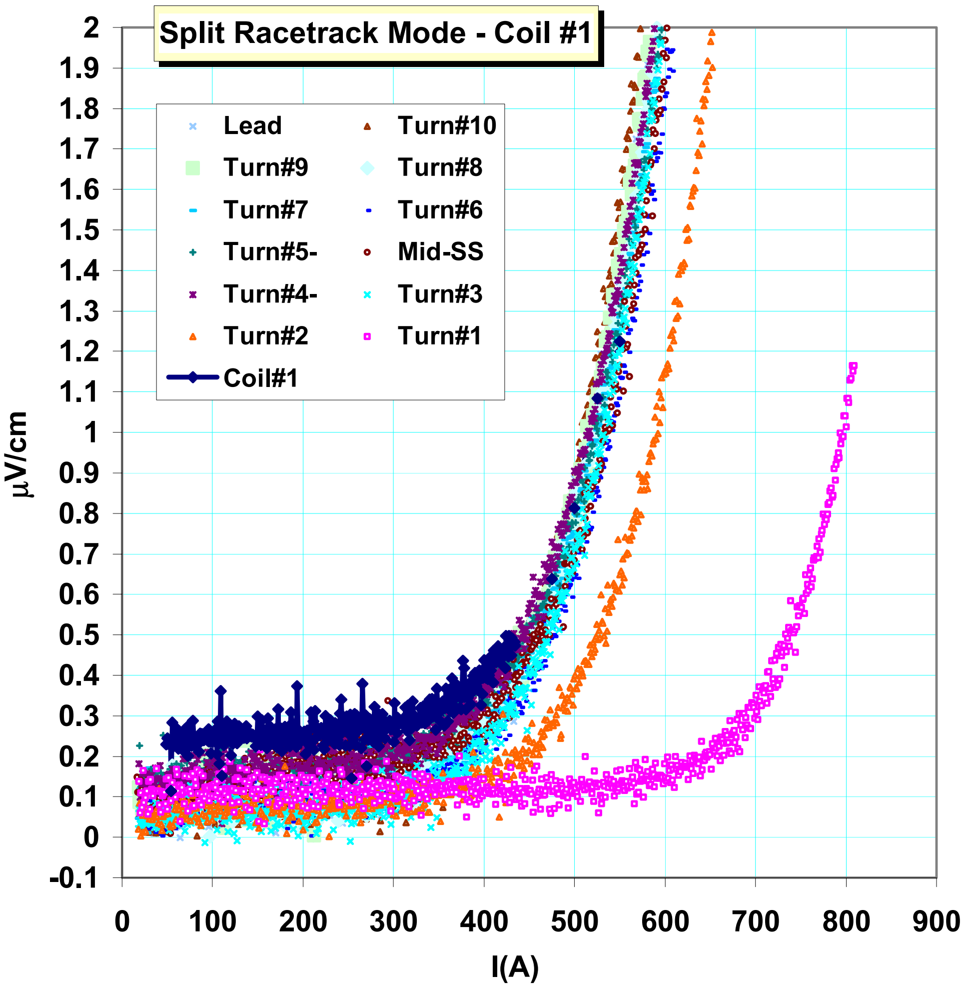
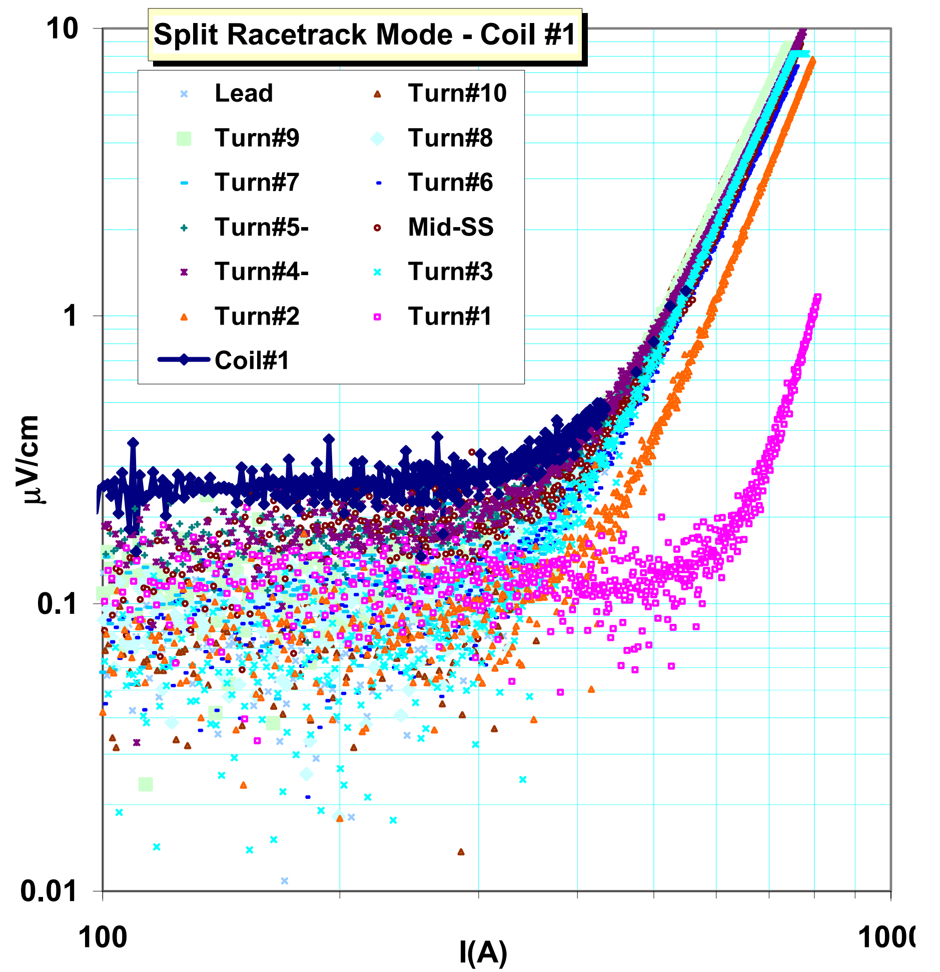
Performance of Coil #1 in Split Racetrack Coil Configuration





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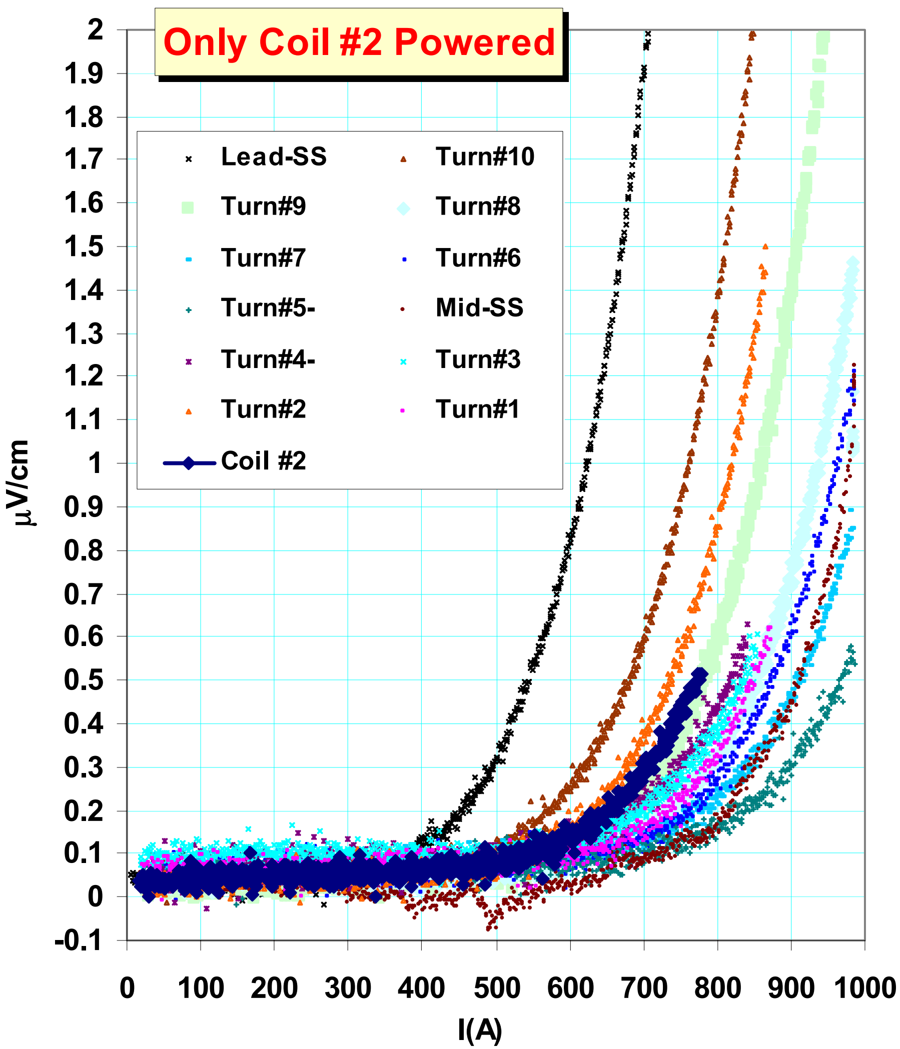
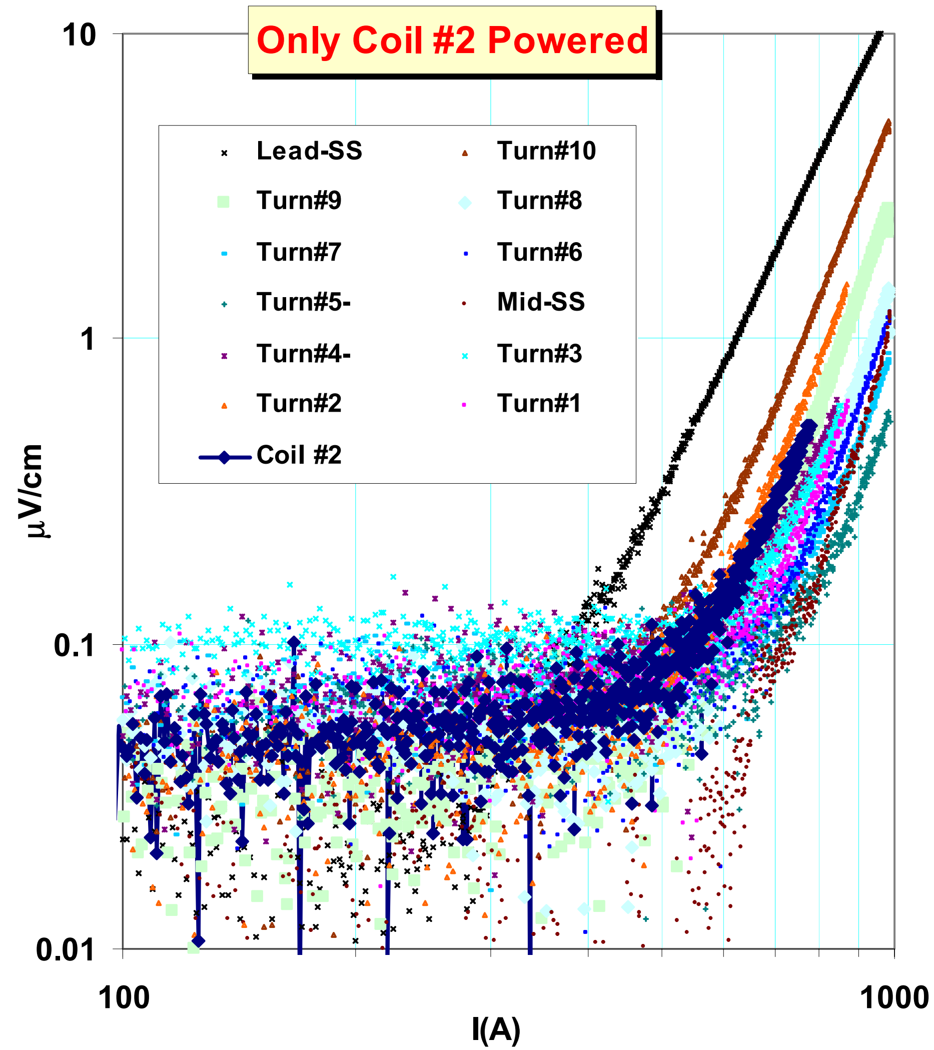
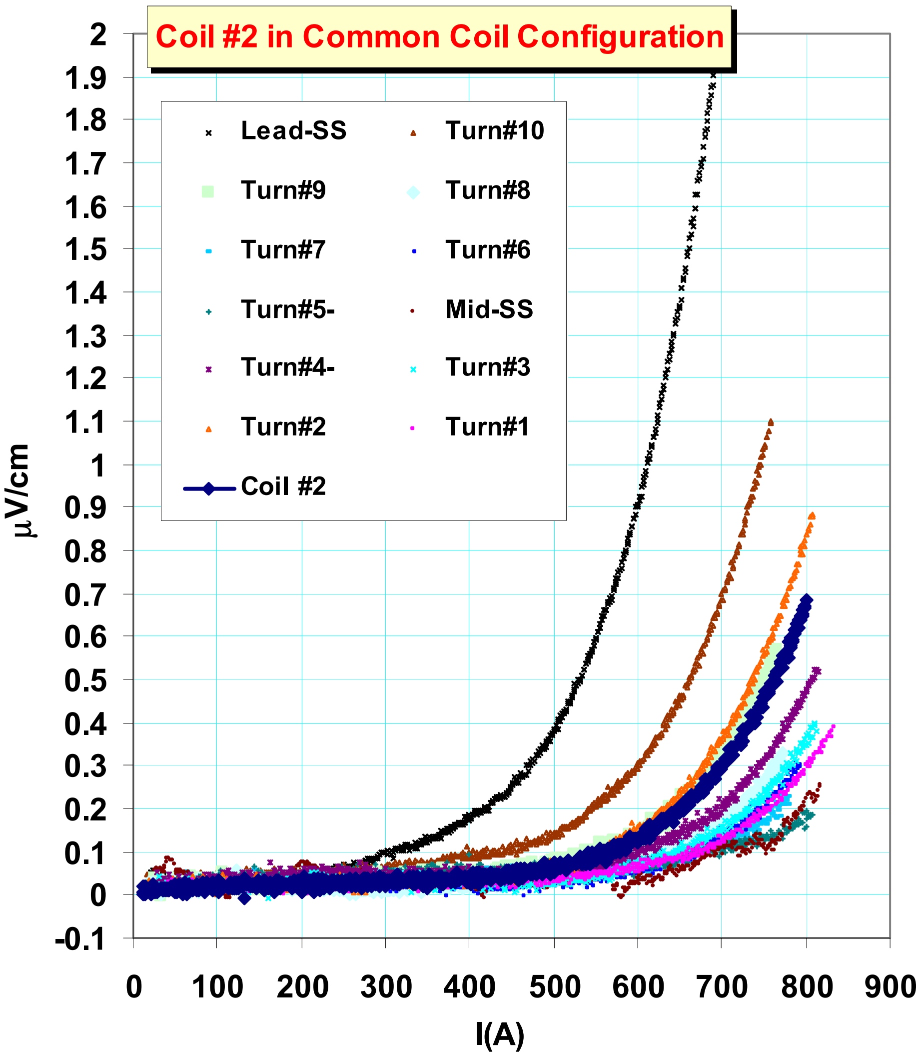
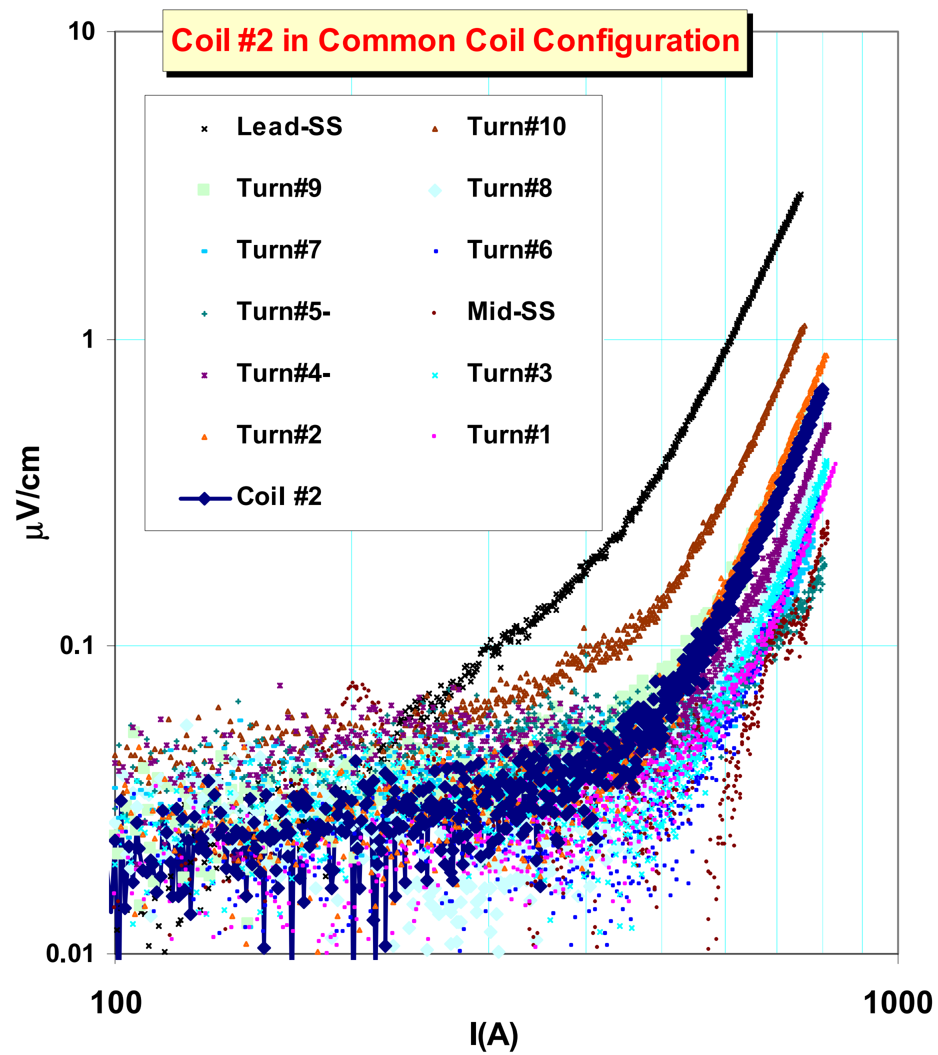
Performance of Coil #2 Powered Alone (Coil #1 off)





Performance of Coil #2 in Common Coil Configuration





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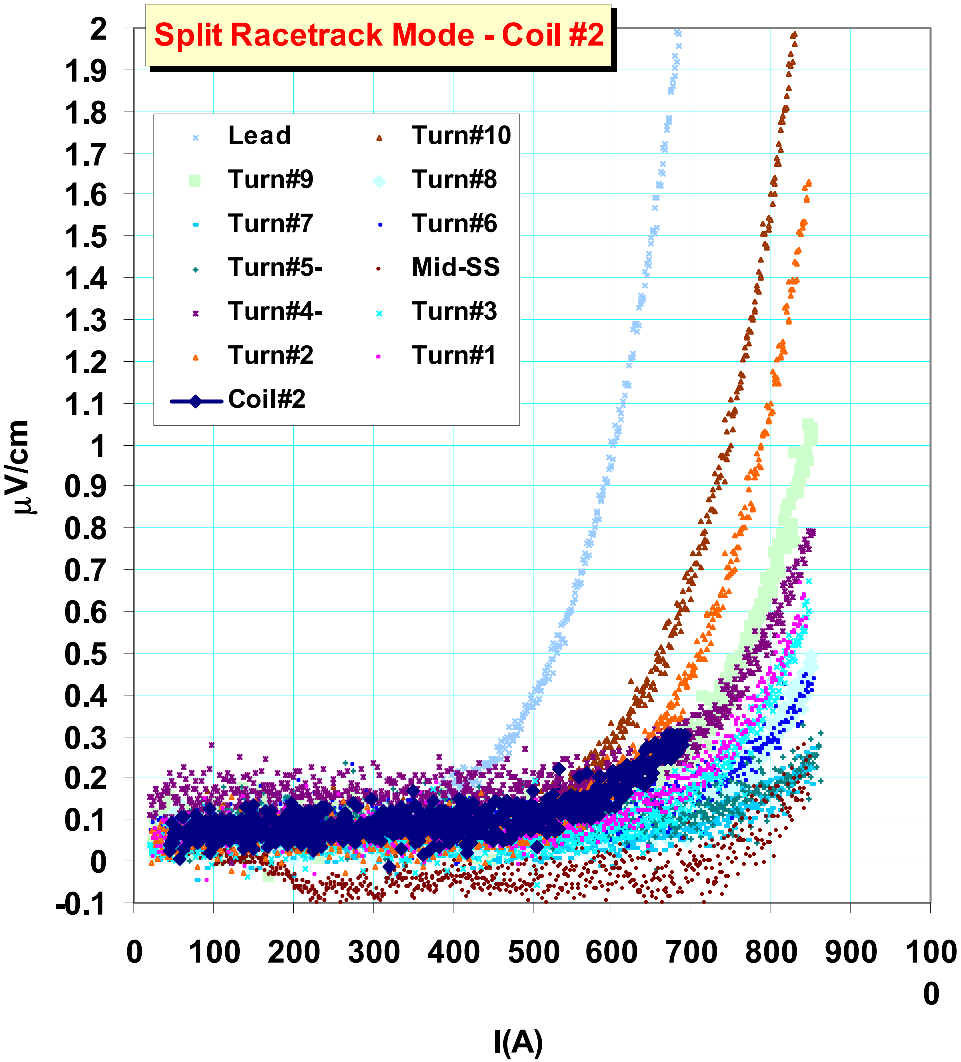
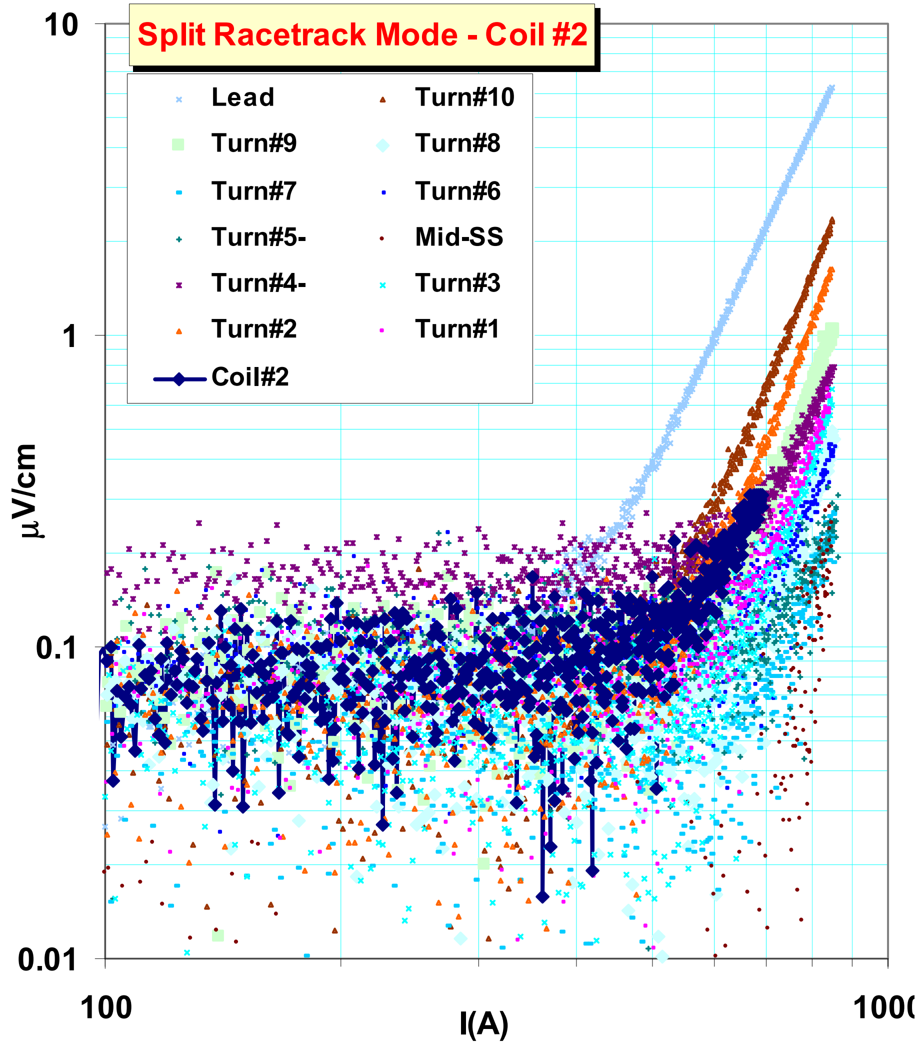
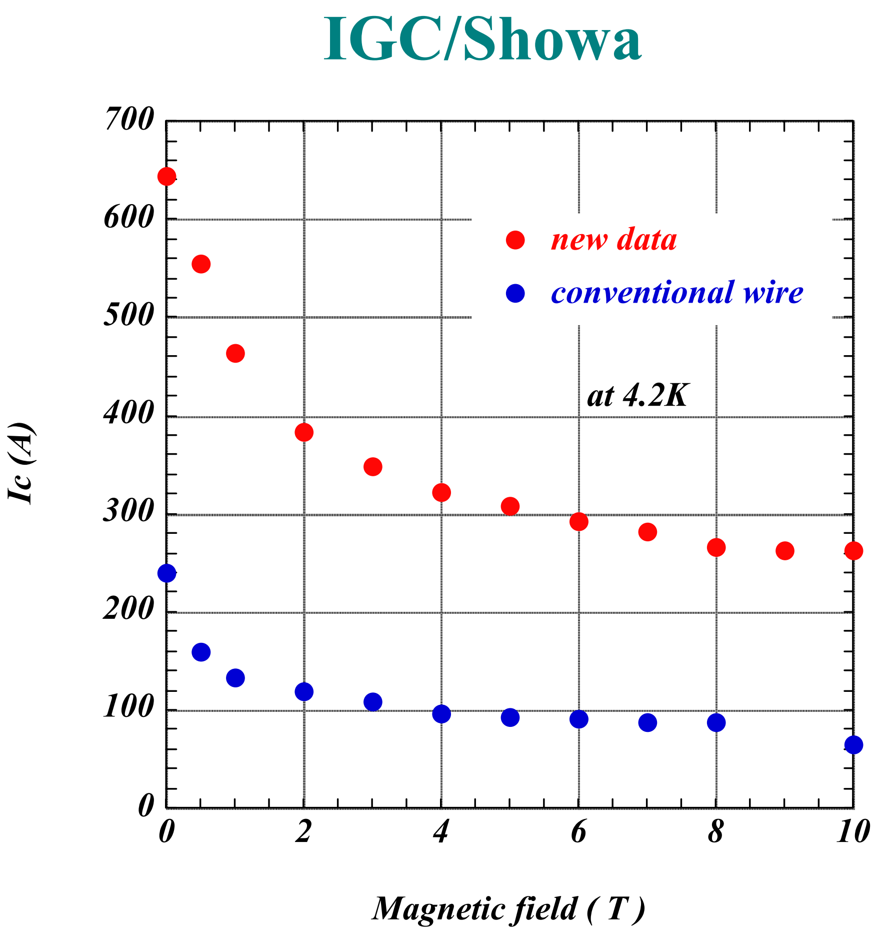
Performance of Coil #2 in Split Racetrack Coil Configuration

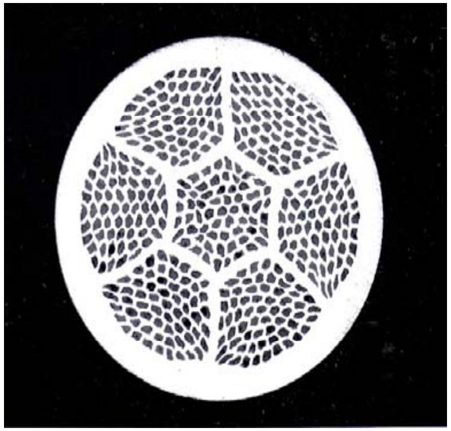




The BSCCO Wire Today

Ic-B characteristics of new wire





I_c (4.2K 0T) : 640A
J_c (4.2K 0T) : 490kA/cm²
Size : 0.81mm[d]
Number of filament : 427
Material of outer sheath : Ag alloy
Material of inner sheath : Ag
Ag/SC ratio : 3.0
Tensile strength (R.T.) : 120MPa

This is about a factor of 5 better than what was used in our coils

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Superconducting Magnet Division

High Field Magnet Work At BNL

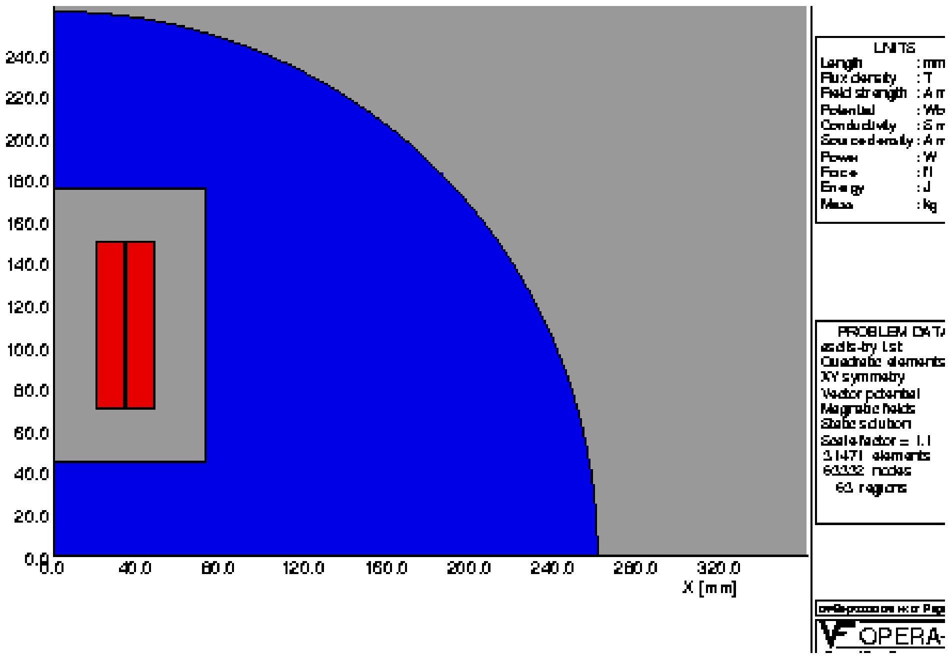
First Phase: Magnet with two "React & Wind" Nb_3Sn coils

Similar technology as HTS (React & Wind) and similar design (Common Coil)

Nb3Sn coils provide high background field for HTS coils in next phase

Second Phase: Additional HTS inner coils in a hybrid design

HTS coils are subjected to high field and high forces



Basic Design Parameters:

Expected Short Sample: ~12.5 T

J_c~ 2000 A/mm^2

2 Layers Nb_3Sn Coils

No. of strand (both layers): 30

Strand diameter (both layers): 0.8 mm

Cu/Sc: 1.0 (inner); 1.86 (outer)

J_{cu}: 1400-1500 A/mm^2 (both layers)

SUMMARY

- We have built and tested HTS common coil magnets at low field with both tapes and cable.
- No significant degradation is observed at low fields, within the level of uncertainty. Early results are positive but more works need to be done.
- Future Plans:
  - Build coils (~3 months) with high performance (~5x better) HTS cable which is waiting for heat treatment now at Showa
  - Build coils with more turns (25) with high performance mixed strand cable we have (IGC/Showa/LBL/BNL collaboration)
  - Test coils in high background field
  - Build ~50 turn coils with high performance HTS cable (longer term goal). Test a set of these coils in the background field of 12 T Nb_3Sn "React & Wind" common coil magnet