DEVELOPMENT AND FIRST TEST OF THE 15 T Nb_3Sn DIPOLE DEMONSTRATOR MDPCT1

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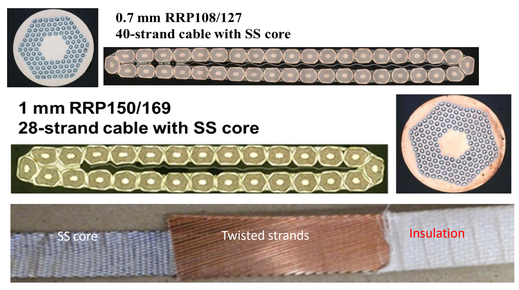
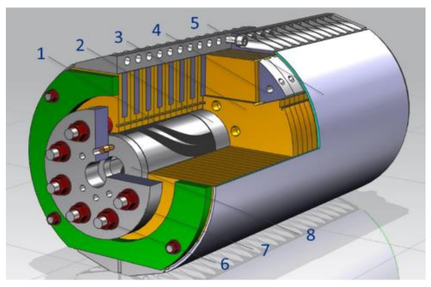
Abstract

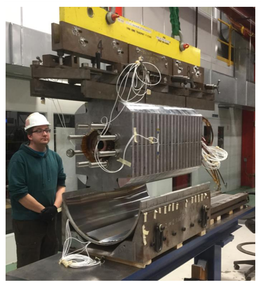
Fermilab in the framework of the U.S. Magnet Development Pro-gram (US-MDP) has developed and fabricated a 15 T Nb_3Sn dipole demonstrator for a post-LHC hadron collider. In June 2019 the magnet was tested and reached a world record field in the aperture of 14.1T at 4.5 K.

MAGNET DESIGN AND FABRICATION

- The coil pre-stress is provided by the mid-plane and coil-yoke shims, the yoke-clamp interference, the yoke-skin shims. During and after magnet cooling-down, it is controlled by the size of the vertical gap between the left and right yoke blocks. Transverse structure rigidity is provided by the rigidity of the iron laminations, aluminum clamps and stainless steel skin.







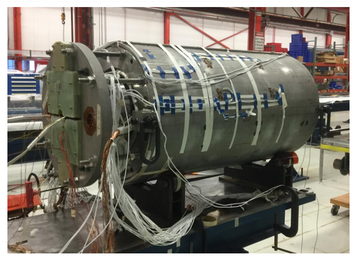


Table 1: MDPCT1 Parameters.

Parameter	Value
Magnet aperture, mm	60
Magnet outer diameter, mm	612
Geometrical length including splice box, m	1.46
Total magnet weight, kg	2390
Short sample bore field at 4.5 K B_{ssl}(4.5K), T	15.16
Short sample bore field at 1.9 K B_{ssl}(1.9K), T	16.84
Design bore field B_{des}, T	15.0

MAGNET TEST PLAN

- MDPCT1 was tested at the FNAL Vertical Magnet Test Facility in June 2019.
- Magnet test program in this test run was focused on the magnet training and magnetic measurements.
- The magnet training was performed at 1.9 K to the target field of ~14 T with the current ramp rate of ~20 A/s.
- Magnetic measurements were performed using 26 mm and 130 mm long, and 26 mm wide 16-layer Printed Circuit Board (PCB) probes. The probe rotation speed was within 0.75-1 Hz.
- The field induction *B* in magnet aperture was represented in terms of harmonic coefficients defined in the series expansion

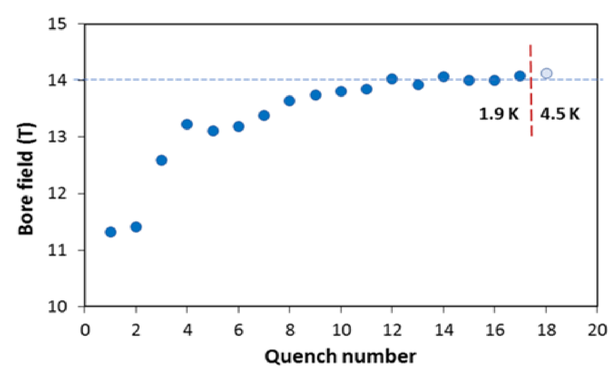
$$B_y + iB_x = B_1 10^{-4} \sum_{n=1}^{\infty} (b_n + ia_n) \left(\frac{x+iy}{R_{ref}} \right)^{n-1}$$

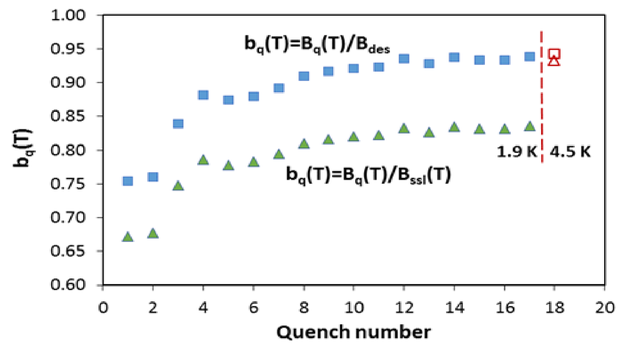
where B_x and B_y are horizontal and vertical field components in the Cartesian coordinate system, b_n and a_n are *2n*-pole "normal" and "skew" harmonic coefficients at the reference radius R_{ref}=17 mm.

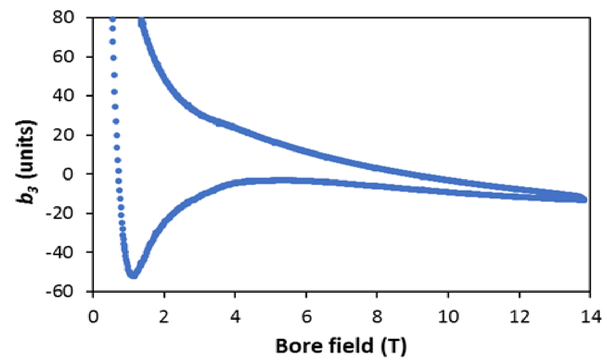
Table 2: Geometrical Harmonics (R_{ref}=17 mm)

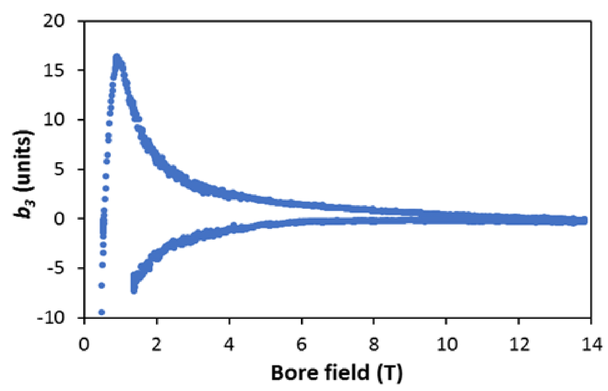
n	2	3	4	5	6	7	8	9
b_n	3.0	13.0	1.1	1.4	0.4	0.6	-0.2	0.3
a_n	-3.0	-5.2	-0.6	-0.2	-0.3	-0.1	-0.2	0.5

TEST RESULTS









CONCLUSION

- **Fermilab has developed and tested a 15 T Nb_3Sn dipole demonstrator for a post-LHC hadron collider. The magnet was assembled with lower coil pre-load to achieve 14 T and minimize the risk of coil damage during assembly.**
- **In the first test the magnet after short training reached 14.1 T at 4.5 K or 94% of its design limit, which is the new world record for accelerator magnets.**
- **All the measured geometrical harmonics, except for a_2, a_3, b_2, b_3, are small, on the level of 1 unit or less. The coil magnetization effect at low fields is large due to the high critical current density and relatively large sub-element size in the contemporary Nb_3Sn strands. The iron yoke saturation effect in MDPCT1 starts at fields above 2.5 T and it is also large. Both effects are consistent with the theoretical predictions for used iron and superconductor magnetic properties, and the magnet yoke geometry.**
- **The eddy current effect on the *TF* and field harmonics in MDPCT1 was suppressed by using a stainless-steel core inside both cables.**

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