NED Status Report

Gijs de Rijk
(CERN)

CERN
31 October 2007

CARE/NED JRA

•Following the 2003 EU peer review, the scope of the NED program was revised to focus on Nb_3Sn conductor and insulation development.

•The NED JRA has been articulated around four Work Packages and one Working Group

1 Management & Communication (M&C),

2 Thermal Studies and Quench Protection (TSQP),

3 Conductor Development (CD),

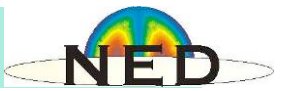
4 Insulation Development and Implementation (IDI),

5 Magnet Design and Optimization (MDO) Working Group.

- It involves 7 institutes (8 laboratories)

- Total budget: ~2 M€; EU grant: 979 k€ (over ~3 years).

NED/TSQP Work Package



- The TSQ Work Package includes two main Tasks

  – development and operation of a test facility to measure heat transfer to helium through Nb_3Sn conductor insulation to investigate temperature margins of superconducting magnet coils under heavy beam losses

  (CEA and WUT; Task Leader: B. Baudouy, CEA)

  To be completed by 15 December 2007

  – quench computation, so as to study the protection of NED-like, high-field Nb_3Sn accelerator magnets

  (INFN-Mi; Task Leader: G. Volpini).

  Completed

NED Heat Transfer Task (1/4)

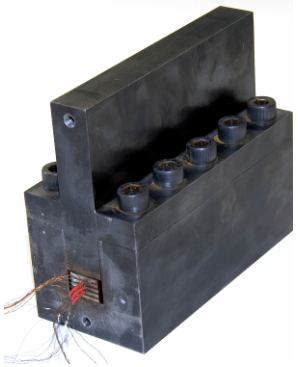
- The first part of the Heat Transfer Task was to design and build a new He-II, double-bath cryostat.

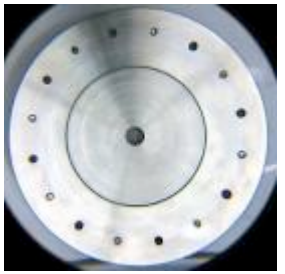
- The cryostat was built by Kriosystem in Poland under the supervision of Wroclaw Technical University according to specifications written by CEA.

- The cryostat was delivered to CEA on 20 Sept. 2005 and was commissioned in September 2006

NED Heat Transfer Task: 06/07 program

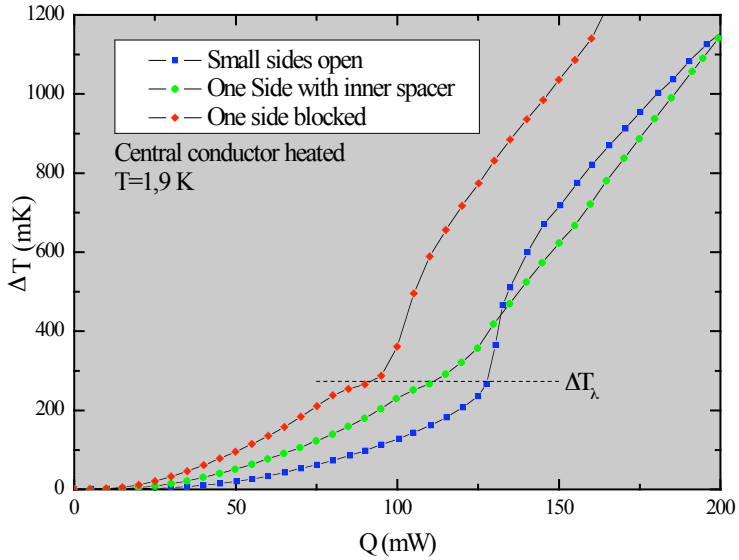
- November 2006 — J. Polinski , B. Baudouy
  - first successful test of a stack sample
- January 2007
  - Test of Saclay sample with 17 tons (original load)
- March 2007
  - Test of Saclay sample: one flank side thermally insulated
  - Stack: First wrapping test with *ceramic* insulation
  - Test of first *ceramic* insulation stack sample
- April 2007
  - 1D: Test of RAL insulation In HeII
- From July 2007
  - Ceramic insulation with different loads
  - Saclay sample with one inter layer spacer (CERN)
- Program on LHC samples and models at CERN (D. Richter)
- November: final report



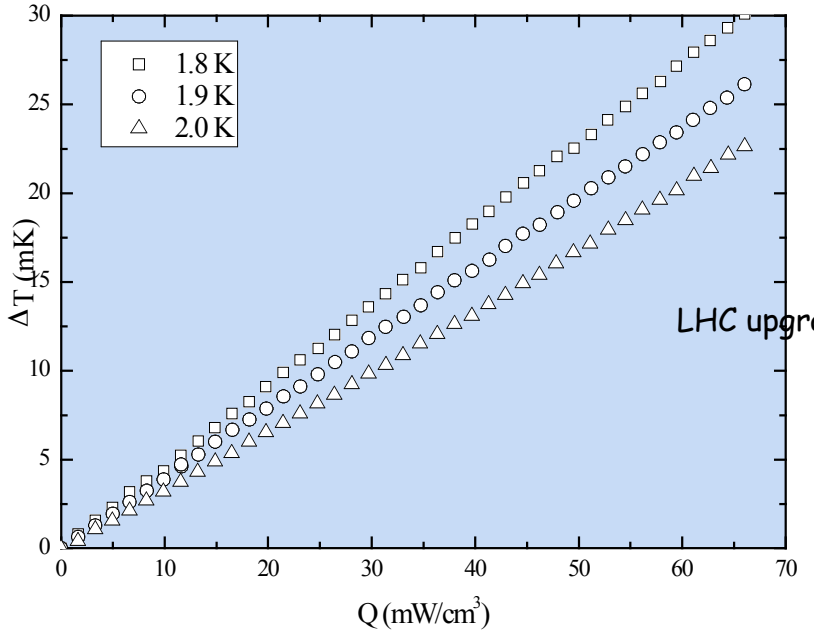


NED Heat Transfer Task

- LHC insulation



- CEA ceramic insulation



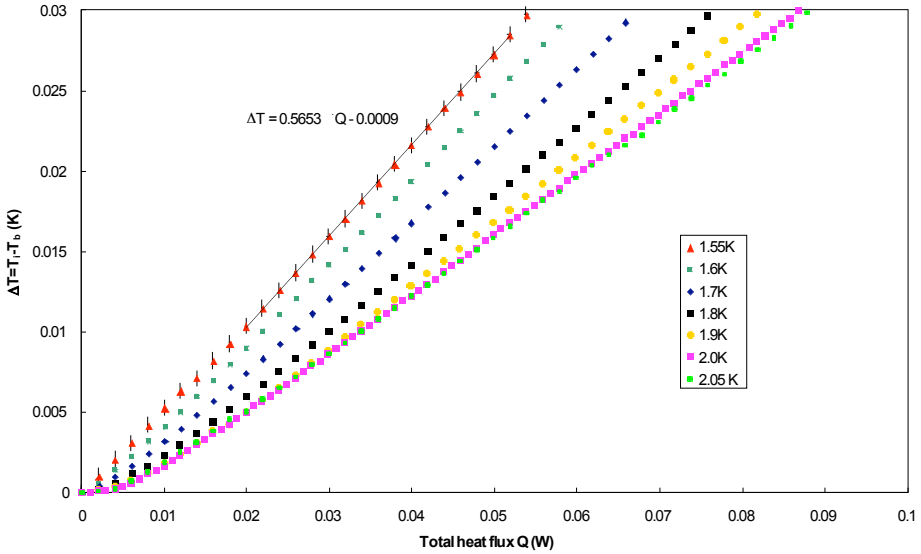
LHC upgrade beam Losses

Very small ΔT, at least **one order of magnitude smaller** than for the LHC insulation tests

LHC beam Losses

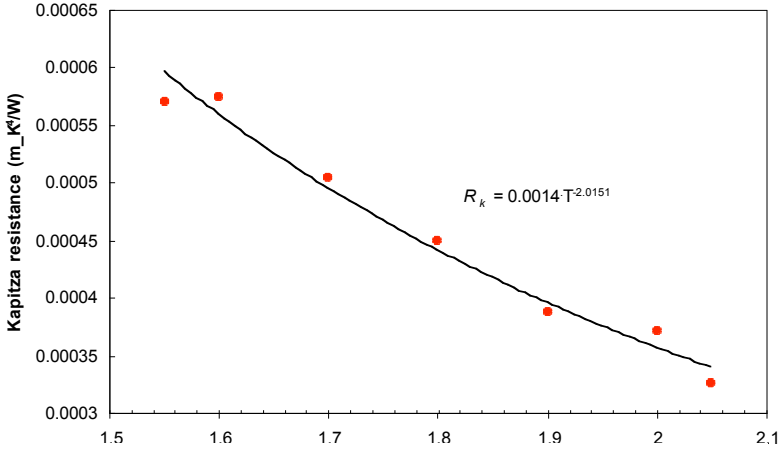
NED Heat Transfer Task: RAL insulation

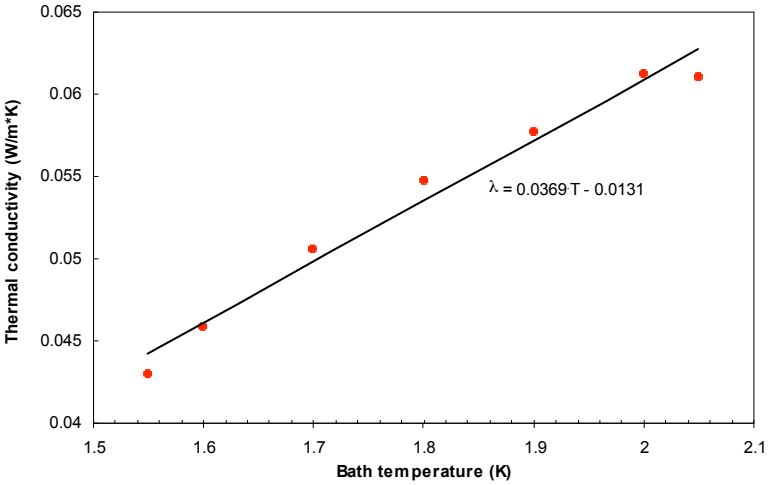
- RAL insulation
  - Example of Measuring Results, l=0.073 mm



Evolution of the temperature difference across the sample with heat flux as a function of the bath temperature.

  - Kapitza Resistance and Thermal Conductivity





NED-CD Work Package

- The CD Work Package includes two main Tasks
  - conductor development

    two industrial contracts under CERN supervision: Alstom/MSA (F) and EAS/SMI (NL/D); Task Leader: L. Oberli
  - conductor characterization

    (CEA, INFN-Ge, INFN-Mi, and TEU; Task Leader: A. den Ouden, TEU)

- It is the core of the Program and absorbs ~70% of the EU funding.

- It is complemented by two extensions of scope
  - FE wire model development to simulate cabling effects

    (INFN-Ge & CERN; Task Leader: S. Farinon, INFN-Ge),
  - heat treatment study

    (CERN; Task Leader: C. Scheuerlein).

NED-CD: Status of the SMI contract (1)

EAS/SMI completed the **step 2** with the cabling test done at LBNL end of June 2007.

5 cable sections were manufactured varying the cable compaction by changing mainly the mid-thickness of the cable. Each cable section has a length of ~2 m.

All sections were characterized by metallographic examination and a first series of critical current measurements was performed by CERN on extracted strands.

The first results indicate a reasonable degradation between 4 and 8%, which is already a very good result.

NED-CD: Status of the SMI contract (2)

The green light was given to SMI-EAS to start the total strand production.

- EAS acquired the PIT technology of SMI in December 2006.
- Total strand production (12.7 km of strand) will be done under the responsibility of EAS.
- The delivery time of the strand is foreseen for end of February 2008.
- EAS has declined to take responsibility for cabling and the cabling cost will be deduced from the contract.
- The cabling will be done under CERN's responsibility (either at LBNL or at CERN).
- A smaller 14 strand cable will be produced for the Short Model Magnet program

NED-CD: Status of the Alstom contract (1)

- The characterization at 12 T and 4.2 K of the step 2 billet #1 (B1-14508) available in January 2007 has continued:

240 h at 660 C :	1874 A/mm^2
160 h at 660 C :	1818 A/mm^2
100 h at 660 C :	1840 A/mm^2
50 h at 660 C :	1896 A/mm^2

- The critical current density at 12 T is much lower than expected even though the Sn content measured in the A15 phase is at the stoichiometry (24 to 25 at. % Sn).
- After drawing the wire from 1.25 mm to 0.83 mm, the critical current density has increased to ~ 2100 A/mm^2, confirming the sound design of the sub-elements.

NED-CD: Status of the Alstom contract (2)

Fabrication Status:

3 sub-elements have been launched in fabrication in 2007 to reach the NED specification in addition to the first 3 billets produced end of 2006.

#4 B1-21204: the Nb barrier was produced according to the process used for the billet B1-88452. 114 sub-elements were stacked in the final billet instead of 78.

#5 B2-14508: same sub-element as for B1-21204 but with NbTa filaments. The final billet will be mounted with 78 sub-elements. Expected Jc: > 2500 A/mm^2

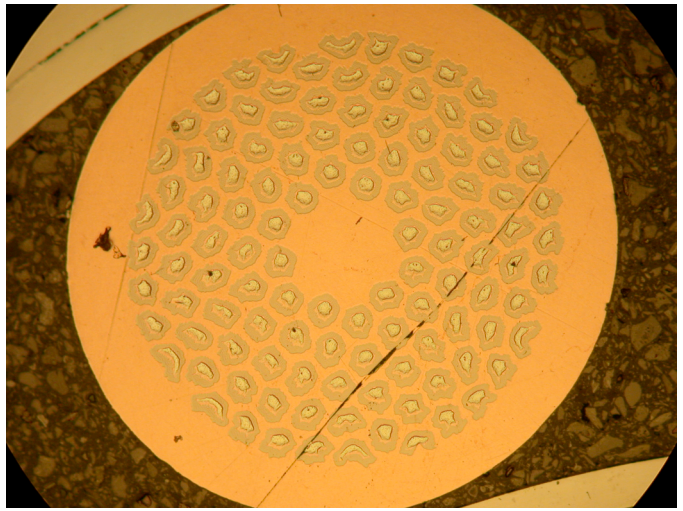
#6 B3-14508: same sub-element as for B1-21204 but with a Nb tube coated with Cu. Expected Jc: ~ 2500 A/mm^2

NED-CD: Status of the Alstom contract (3)

Result for **#4** B1-21204

- Many breakages occurred during drawing starting at a diameter of 36 mm and continuing up to 7 mm.
- Drawing was better below 7 mm in diameter as seen on one part of the billet drawn to 1.25 mm.
  - 114 sub-elements
  - Strand diameter = 1.250 mm
  - Cu/non-Cu = 1.67
  - **$J_c^{non\text{-}Cu}$(12 T) ~ 1800 A/mm²**

    with 50 h at 660 C.
  - Few sub-elements broken as seen from Cu/Sc measurement.



- Results for #5 and #6 are expected for November 2007

NED-CD: Status of the Alstom contract (4)

Main problems to be solved and actions taken

- Cohesion: a major issue in the actual fabrication process, cohesion is the cause of the strand breakages.
- Drawing conditions: Alstom will buy a new set of drawing dies which should be better adapted to Nb_3Sn strand and which will be used for billets # 4 and # 5.
- Design of the final billet: up to now only the final billets with 78 sub-elements were successful.
- Ic optimization: A final heat treatment cycle has to be found to get small grain size and a full reaction
- To solve the problems related to cohesion, a process based on extrusion of the sub-element was decided in January 2006. The sub-elements with thicker Nb barrier were successfully produced this year and they are nearly ready for restacking.
- The final billet is expected for November 2007.

NED-CD: Conductor characterization (1)

- EAS/SMI PIT B215 wire
  - ~ 1 km wire produced in a single length
    - 288 filaments (~ 50 µm)
    - D_{strand} = 1.257 mm
    - Adequate Cu/non-Cu ratio of 1.22
  - After following HT schedule: 50 °C/h, 84 h @ 675 °C
    - I_c=756 A @ 15 T, 4.2 K (only 8 % below spec.), n=74, J_c=1350 A/mm^2
    - I_c=1397 A @ 12 T, 4.2 K (~ 15 % below spec.), n=80, J_c~ 2500 A/mm^2 RRR ~ 80

Combination of high I_c at 12 T and fine filament size: *world record!!*

- Test pieces of cable: Critical current measurements on extracted wires were done at CERN, LASA and Twente to assess cabling degradation: a 4%-8% degradation was measured

NED-IDI Work Package (1)

- The IDI Work Package includes two main Tasks

  – studies on "conventional" insulation systems relying on ceramic or glass fiber tape and vacuum-impregnation by epoxy resin

    (CCLRC/RAL; Task Leader: S. Canfer)

  Completed

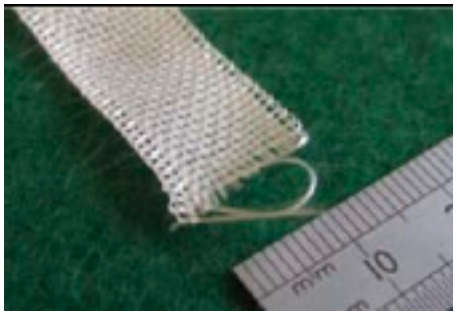
  – studies on "innovative" insulation systems relying on pre-impregnated fiber tapes and eliminating the need for a vacuum impregnation

    (CEA; Task Leader: F. Rondeaux).

  Waiting for report (December 2007)

NED-IDI Work Package (2)

- CCLRC/RAL is evaluating a polyimide-sized glass fiber tape that is able to sustain the required Nb_3Sn heat treatment without degradation and which seems a promising solution to conventional insulation



Polyimide-sized S2 glass fiber tape (Courtesy S. Canfer, CCLRC/RAL)

- The Innovative Insulation Task is built upon an ongoing R&D program at CEA which has demonstrated the feasibility of such a system (2 patents); the efforts are now concentrated on characterizing and improving the mechanical properties of the insulation.

Heat-treated conductor stack with CEA innovative insulation (Courtesy F. Rondeaux & P. Fourcade, CEA)

NED-MDO Working Group (1)

- The Magnet Design and Optimization (MDO) Working Group is made up of representatives from CCLRC, CEA, CERN and CIEMAT
  (Chairman: F. Toral, CIEMAT)

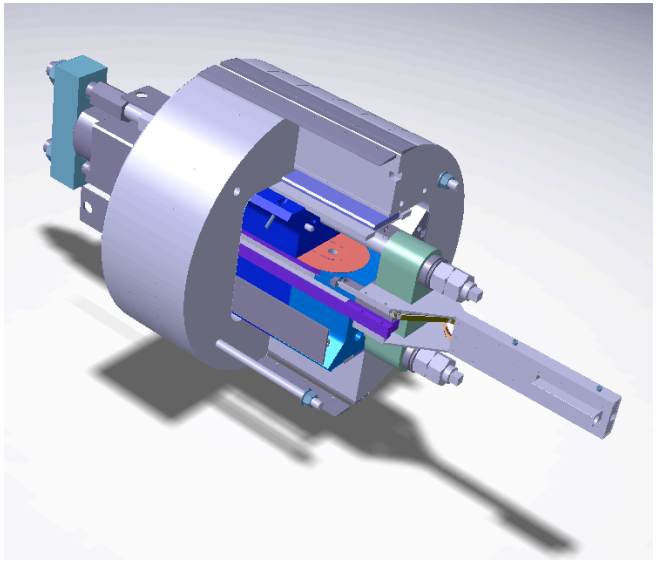
- The Working Group has **completed** its comparison of selected 2D magnetic configurations.

- In parallel, CERN has **completed** its optimization of 2D 88-mm-aperture, cosθ, layer magnetic design (Reference Design V2) and CCLRC/RAL has undertaken a 2D mechanical design

- CCLRC/RAL is pursuing (outside NED deliverables) its development of a comprehensive (ANSYS- based) mechanical model of baseline, 88-mm-aperture, cosθlayer design throughout the various steps of manufacturing, cooldown and energization.

Next Step: Short Model Coil SMC

- Participant funding only (formally outside FP6-CARE-NED)
- CCLRC/RAL, CEA and CERN have agreed to manufacture and test a series of LBNL-type Short Model Coils wound from NED-sub-cables so as to investigate
  - cable and insulation performances in real coil environment,
  - design limits for transverse and longitudinal loads.
- Coil design finished, cold mass design being finalized, first winding tests with dummy cable two weeks ago by RAL-CERN team (interactions with LBNL). First magnet foreseen to be tested in Sept-Oct at CERN



- (Courtesy P. Ferracin, LBNL)

Deliverables

NED	24	Final report on Heat Transfer Measurements	Report	WP2	CEA-WUT		Dec 07
NED	30	Report on innovative insulation	report	WP4	CEA		Dec 07
NED	25	Final wire production	Prototype	WP3	CERN		March 08 July 08
NED	26	Final report on wire characterization	report	WP3	CERN		March 08 July 08
NED	27	Final cable production	Prototype	WP3	CERN		March 08 July 08
NED	28	Final report on cable performances	report	WP3	CERN		March 08 July 08

Publications in 2007

1. S. Farinon, T. Boutboul, A. Devred, D. Leroy, L. Oberli,NB3SN wire layout optimization to reduce cabling degradationMT20
2. T. Boutboul, A. den Ouden, A. Devred, P. Fabbricatore4, M. Greco, D. Leroy, L. Oberli, D. Pedrini and G. Volpini,Nb3Sn conductor development and characterization for NEDEUCAS 2007
3. M. Di Michiel, C. Scheuerlein,Phase transformations during the reaction heat treatment of powder-in-tube Nb3Sn superconductorsSupercond. Sci. Technol. 20, (2007) L55-L58
4. C. Scheuerlein, M. Di Michiel, A. Haibel,On the formation of voids in Nb3Sn superconductors", Appl. Phys. Lett., 90, 132510, (2007)
5. Polinski J., Canfer S., Ellwood G., Baudouy B.,Low Temperature Heat Transfer Properties of Conventional Electrical Insulation For The Next European Dipole.CEC-ICMC 2007