9 June 2006

CARE/JRA4: Status Report of the 1st Quarter of 2006
Title: Next European Dipole (NED)

Coordinator: A. Devred (CEA & CERN), Deputy: A. den Ouden (TEU)

Participating Laboratories and Institutes:

Institute (Participant Number)	Acronym	Country	Coordinator	Scientific Contact	Associated to
CCLRC-RAL (20)	CCLRC	GB	P. Norton	D.E. Baynham	
CEA/DSM/DAPNIA (1)	CEA	F	R. Aleksan	A. Devred	
CERN (17)	CERN	CH	G. Guignard	D. Leroy	
CIEMAT (16)[a)]	CIEMAT	S	A. Faus-Golfe	F. Toral	CSIC
INFN/Milano-LASA (10)	INFN-Mi	I	S. Guiducci	G. Volpini	INFN
INFN/Genova (10)	INFN-Ge	I	S. Guiducci	P. Fabbricatore	INFN
Twente University (11)	TEU	NL	A. den Ouden	A. den Ouden	
Wroclaw University (15)	WUT	PL	M. Chorowski	M. Chorowski	

[a)] New collaborator with respect to CARE Annex I.

Main Objectives: Research and Development on high performances Nb_3Sn cables and high field magnets design and manufacturing to push the technology beyond present LHC limits.

Cost:

Total Expected Budget	Allocated EU Funding
2093 k€	980 k€

OUTLINE

1 MANAGMENT

Table 1.a: List of participants and of their implication
in the NED Work Packages (**C**: Coordination, X: Participation).
The overall management is carried out by CEA.

Number	Participant	WP1 M&C	WP2 TSQP	WP3 CD	WP4 IDI	WG MDO[a)]
1	**CEA**	**C**	X	X	X	X
10	**INFN**	X	**C**	X		
	INFN-Ge	X		X		
	INFN-Mi	X	**C**	X		
11	**TEU**	X		X		
15	**WUT**	X	X			
16	**CSIC**	X				**C**
	CIEMAT	X				X
17	**CERN**	X		**C**		X
20	**CCLRC**	X	X		**C**	X
	CCLRC-RAL	X	X		**C**	X

[a)] The Working Group on Magnet Design and Optimisation (WGMDO) is an extension of scope with respect to CARE Annex 1.

Table 1b: Calendar of meetings, workshops and events (co)organized by NED or with NED contributions in 2004.

NA/JRA Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CARE steering meeting		**23 Paris**				**24-25 Warsaw**					**5 Hamburg**	
NED steering meeting	**8 CERN**		**25 CERN**				**8 CERN**			**28-29 Saclay**		
NED ESAC meeting			**24 CERN**									
HHH network meeting			**22-24 WAMS Archamps**								**8-12 HHH CERN**	
Participation to meetings of other collaborations												
US-LARP						**17-18 LAPAC FNAL**						
Conferences & workshops with activity contrib.												
EPAC'04							**5-9 Lucerne**					
ASC'04										**3-8 Jacksonville**		

Table 1b (Cont.): Calendar of meetings, workshops and events (co)organized by NED or with NED contributions in 2005.

NA/JRA Activity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
CARE SC meeting				**5-6 CERN**					**5-6 Paris**		**21-25 CERN**	
NED SC meeting	**20 CERN**			**14 CERN**			**7 WUT**				**24 CERN**	
NED ESAC meeting												
HHH/AMT meeting			**3-4 Beam Loss CERN 22-23 Insulation CERN**						**26-27 Tooling CERN**	**24-28 ECOMAG Frascati**		
Meetings of other collab.												
US-LARP						**1-2 Review FNAL**					**2-4 Review CA**	
Conf. & workshops with NED contrib.												
PAC'05					**16-20 Knoxville**							
SPIE								**28-02 Warsaw**				
CEC /ICMC'05								**29-02 Keystone**				
EUCAS'05									**11-15 Vienna**			
MT'19									**19-23 Genova**			

Table 1b (Cont.): Calendar of meetings, workshops and events (co)organized by NED or with NED contributions in 2006.

NA/JRA Activity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
CARE SC meeting				**11 LPNHE**								
NED SC meeting		**23 CERN**				**1 CIEMAT**						
NED ESAC meeting												
HHH/AMT meeting				**3-7 WAMDO CERN**								
Meetings of other collab.												
US-LARP					**10-12 Review BNL**	**14-16 Review FNAL**						
Conf. & workshops with NED contrib.												
EPAC’06						**26-30 Edimburgh**						
ICEC 21 /CEC’06							**17-21 Prague**					
ASC 06								**27-1 Seattle**				

Table 1c: List of meetings, workshops and events (co)organized by or pertinent to NED in 2004.

Date	Title /Subject	Location	Main Organizer	Number of Participants	Comments and Web Site
Jan 8	NED SC	CERN	CEA&CERN	10	http://lt.tnw.utwente.nl/project.php?projectid=9
Mar 22-24	WAMS	Archamps	CERN	100	http://amt.web.cern.ch/amt/events/workshops/WAMS2004/wams2004_index.htm
Mar 24	NED ESAC	CERN	CEA&CERN	15	http://lt.tnw.utwente.nl/project.php?projectid=9
Ma 25	NED SC	CERN	CEA&CERN	12	http://lt.tnw.utwente.nl/project.php?projectid=9
May 19	NED WGCC	CERN	TEU	7	http://lt.tnw.utwente.nl/project.php?projectid=9
May 19	NED WGMDO	CEA	CEA	9	http://lt.tnw.utwente.nl/project.php?projectid=9
Jul 8	NED SC	CERN	CEA&CERN	15	http://lt.tnw.utwente.nl/project.php?projectid=9
Oct 28	NED WGCC	CEA	TEU	7	http://lt.tnw.utwente.nl/project.php?projectid=9
Oct 29	NED SC	CEA	CEA	23	http://lt.tnw.utwente.nl/project.php?projectid=9
Nov 8-11	CARE-HHH	CERN	CERN	50	http://care-hhh.web.cern.ch/care-hhh/
Dec 17	NED WGMDO	CIEMAT	CIEMAT	7	http://lt.tnw.utwente.nl/project.php?projectid=9

Table 1c (Cont.): List of meetings, workshops and events (co)organized by or pertinent to NED in 2005.

Date	Title /Subject	Location	Main Organizer	Number of Participants	Comments and Web Site
Jan 20	NED SC	CERN	CEA&CERN	22	http://lt.tnw.utwente.nl/project.php?projectid=9
Feb 2	NED WGCC	LASA	INFN-Mi	6	http://lt.tnw.utwente.nl/project.php?projectid=9
Mar 3-4	HHH Beam Losses	CERN	CERN	50	http://care-hhh.web.cern.ch/care-hhh/
Mar 22-23	HHH/AMT Insulation	CERN	CERN	25	http://amt.web.cern.ch/amt/
Apr 13	NED WGMDO	CERN	CIEMAT	8	http://lt.tnw.utwente.nl/project.php?projectid=9
Apr 14	NED SC	CERN	CEA&CERN	18	http://lt.tnw.utwente.nl/project.php?projectid=9
May 3	NED WGCC	CERN	TEU	8	http://lt.tnw.utwente.nl/project.php?projectid=9
Jun 14	NED WGMDO	CCLRC	CIEMAT	11	http://lt.tnw.utwente.nl/project.php?projectid=9
Jul 7	NED SC	WUT	CEA&CERN	14	http://lt.tnw.utwente.nl/project.php?projectid=9
Oct 26-28	HHH/AMT	Frascati	CERN		http://amt.web.cern.ch/amt/
Nov 22	NED WGCC	CERN	TEU	7	http://lt.tnw.utwente.nl/project.php?projectid=9
Nov 22	NED WGMDO	CERN	CIEMAT	12	http://lt.tnw.utwente.nl/project.php?projectid=9
Nov 23	HHH/AMT	CERN	CERN		http://amt.web.cern.ch/amt/
Nov 24	NED SC	CERN	CEA&CERN	26	http://lt.tnw.utwente.nl/project.php?projectid=9

Table 1c (Cont.): List of meetings, workshops and events (co)organized by or pertinent to NED in 2006.

Date	Title /Subject	Location	Main Organizer	Number of Particip ants	Comments and Web Site
Feb 23	NED SC	CERN	CEA&CERN	17	http://lt.tnw.utwente.nl/project.php?projectid=9
April 3-6	HHH/AMT WAMDO	CERN	CERN	100	http://amt.web.cern.ch/amt/
April 7	NED WGMDO	CERN	CIEMAT	7	http://lt.tnw.utwente.nl/project.php?projectid=9
June 1	NED SC	CIEMAT	CEA&CERN		
July 11	NED WGMDO	CERN	CIEMAT		

Table 1d: List of milestones and deliverables due in 2004.

Deliverable Number	Milestone Number	Name	Work Package/Task Number	Delivered by	Planned (in months)	Achieved (in months)	EDMS Number
04/14		Final Report on Wire and Cable Specifications	CD/3.3	CERN	6	6	475443
		Report on Specifications for Conductor Insulation	IDI/4.2	CCLRC	6	7	548037V5
		Report on Definition of the Test Programme for Conductor Insulation[a)]	IDI/4.3&4.4	CCLRC&CEA	7	10	548038V2
		Status Report on Conductor Development[b)]	CD/3.4	CERN	-	3	Restricted Access
04/15		Design Report on 15 T Dipole Magnet	CD/3.2	CERN	12	13	555826
		Interim Report on Quench Protection	TSQP/2.3	INFN-Mi	12	13	555756

[a)] Scope of report has been extended to include test programme on innovative insulation (Task 4.4).
[b)] The milestone entitled “First Results on Wire Development” that was due on 30 June 2005 has been split into two “Status Reports” due on 15 December 2004 and 15 December 2005.

Table 1d (Cont.): List of milestones and deliverables due in 2005.

Deliverable Number	Milestone Number	Name	Work Package/Task Number	Delivered by	Planned (in months)	Achieved (in months)	EDMS Number
05/27		Report on Heat Transfer Facility Commissioning[a)]	TSQP/2.2	CEA&WUT	16		
05/28		Report on Quench Computation	TSQP/2.3	INFN-Mi	18	23	683013
		Status Report on Conductor Development[b)]	CD/3.4	CERN	-	12	Restricted Access
		Interim Report on Heat Transfer Measurements [c)]	TSQP/2.2	CEA	9		
		Interim Report on Wire Characterization [d)]	TSQP/3.5	CEA, CERN, INFN,TEU			
05/29		Report on Conventional Insulation[e)]	IDI/4.3	CCLRC	24		
05/30		Report on Innovative Insulation[f)]	IDI/4.4	CEA	18		

[a)] Report has been delayed until 30 June 2006, due to delay in cryostat delivery and problem with liquid helium level sensor during first test at CEA.

[b)] As already mentioned, the milestone entitled "First Results on Wire Development" that was due on 30 June 2005 has been split into two "Status Reports" due on 15 December 2004 and 15 December 2005.

[c)] Report has been delayed until 31 December 2006 due to delay in postdoc hiring at CEA.

[d)] Interim report has been delayed until 30 June 2006, pending results from both wire manufacturers.

[e)] Report has been delayed until 31 December 2006.

[f)] Report has been delayed until 31 March 2007 due to human resources' problem at CEA.

Table 1d (Cont.): List of milestones and deliverables due in 2006.

Deliverable Number	Milestone Number	Name	Work Package/Task Number	Delivered by	Planned (in months)	Achieved (in months)	EDMS Number
06/24		Final Report on Heat Transfer Measurements[a)]	TSQP/2.2	CEA	36		
06/25		Final Wire Production	CD/3.4	CERN	30		
06/26		Final Report on Wire Characterization	CD/3.5	CEA, CERN, INFN, TEU	30		
06/27		Final Cable Production [c)]	CD/3.6	CERN	36		
06/28		Final Report on Cable Performances	CD/3.7	TEU	36		

[a)] Report has been delayed until 31 June 2007 due to delay in postdoc hiring at CEA.

Table 1e: List of major achievements in 2004.

- The awards of contracts for Nb_3Sn conductor development to Alstom/MSA (France) and SMI (The Netherlands)
- The first design of an 88 mm aperture, 15 T dipole magnet (NED Reference Design V1)

Table 1e (Cont.): List of major achievements in 2005.

- Manufacturing and reception tests of double-bath, He II cryostat for heat transfer measurements
- Detailed computations of thermo-electrical behaviour of NED-like magnets during a quench
- Assembly of first round of billets for NED conductor production at Alstom/MSA and SMI
- Identification of a polyimide-sized, glass fiber tape candidate for conventional conductor insulation
- Iterated design of 88 mm aperture, 15 T dipole magnet (NED Reference Design V2)

Table 1e (Cont.): List of major achievements in 2006.

- Characterization tests of first 1.25-mm-diameter wire produced by SMI.

2 DISSEMINATION

2.1 List of talks

Table 2.1: List of review talks given by NED Collaborators in 2004.

#	Title	Speaker and lab	Location	Date
1	NED Status Report	A. Devred (CEA&CERN) and T. Taylor (CERN) on behalf of the NED Collaboration	KEK, Tsukuba, Japan	9 March 2004
2	Next European Dipole (NED) Overview	A. Devred (CEA&CERN) on behalf of the NED Collaboration	AFF meeting, Belfort, France	25 May 2004
3	Next European Dipole (NED) Overview	A. Devred (CEA&CERN) on Behalf of the NED Collaboration	Department Of Energy (DOE), Washington, DC, USA	16 June 2004
4	Status of the Next European Dipole (NED) Activity of the Coordinated Accelerator Research in Europe (CARE) Project	A. Devred (CEA&CERN) on Behalf of the NED Collaboration	Applied Superconductivity Conference, Jacksonville, FL	6 October 2004

Table 2.1 (Cont.): List of review talks given by NED Collaborators in 2005.

#	Title	Speaker and lab	Location	Date
1	Next European Dipole (NED) Overview	A. Devred (CEA&CERN) on behalf of the NED Collaboration	CERN	4 February 2005
2	Superconducting High Field Accelerator Magnets: Status and Perspectives	A. Devred (CEA&CERN) on behalf of the NED Collaboration	SPIE International Congress on Optics and Electronics, Warsaw	30 August 2005 EDMS 634298
3	Next European Dipole (NED) Status Report	A. Devred (CEA&CERN) on behalf of the NED Collaboration	European Conference on Applied Superconductivity, Vienna	12 September 2005 EDMS 742915
4	Nb_3Sn Wires and Conductors	A. Devred (CEA&CERN)	AFF School on "Conducteurs Supraconductcteurs," Archamps, France	20 October 2005
5	Next European Dipole (NED) Status Report	A. Devred (CEA&CERN) on behalf of the NED Collaboration	CEA/Cadarache	17 November 2005 EDMS 742917
6	Magnetization measurements as a tool for investigating the potential electrical transport current properties of Nb_3Sn superconducting wires	M. Greco (INFN-Ge)	Highlight Talk at CARE General Meeting, CERN	23 November 2005 EDMS 742920
7	Next European Dipole insulation development	S. Canfer (CCLRC)	Highlight Talk at CARE General Meeting, CERN	24 November 2005 EDMS 742925
8	Nb_3Sn Wires and Conductors	A. Devred (CEA&CERN)	CERN	12-13 Dec. 2005 EDMS 742929

Table 2.1 (Cont.): List of review talks given by NED Collaborators in 2006.

#	Title	Speaker and lab	Location	Date
1	Progress in Superconducting Magnets	A. Devred (CEA&CERN)	Bologna University	15 February 2006
2	Next European Dipole (NED) Overview	A. Devred (CEA&CERN) on behalf of the NED Collaboration	WAMDO Workshop, CERN	4 April 2006 EDMS 742932
3	Développement en Europe des conducteurs Nb3Sn pour hautes inductions (in French)	L. Oberli (CERN)	AFF Meeting, Aussois, France	16 May 2006 EDMS 742955
4	High-field accelerator magnet development, e.g., NED	A. Devred (CEA&CERN) on behalf of the NED Collaboration	AFF Meeting, Aussois, France	19 May 2006 EDMS 742932
5	Progress in low Tc superconducting magnets	A. Devred (CEA&CERN) on behalf of the NED Collaboration	LNCMP, Toulouse, France	23 May 2006 EDMS 742959
6	Roadmap towards 15 T dipole magnet	A. Devred (CEA&CERN) on behalf of the NED Collaboration	Magnet Day, CEA/Saclay	3 July 2006
7	Large Superconducting Magnets and the ITER Project	A. Devred (CEA&CERN)	7th SCENET School on Superconducting Materials and Applications	28 July 2006
8	High Field Superconducting Magnet R&D Aimed at LHC Luminosity Upgrade	A. Devred (CEA&CERN), S. Gourlay (LBNL), L. Rossi (CERN) and A. Yamamoto (KEK)	Applied Superconductivity Conference, Seattle, WA	31 August 2006

List of papers

Table 2.2: List of papers issued by NED collaborators in 2004.

#	CARE document type and number	Title	Author(s) and Lab(s)	Reference	Date
1	N/A	High field accelerator magnets beyond LHC	A. Devred (CEA&CERN)	*Proceedings of the 2003 IEEE Particle Accelerator Conference*, IEEE Catalogue 03CH37423, pp. 146–150, 2003	2003
2	N/A	High field accelerator magnet R&D in Europe	A. Devred (CEA&CERN), D.E. Baynham (CCLRC), L. Bottura (CERN), M. Chorowski (WUT), P. Fabbricatore (INFN-Ge), D. Leroy (CERN), A. den Ouden (TEU), J. M. Rifflet (CEA), L. Rossi, O. Vincent-Viry (CERN), G.Volpini (INFN-Mi)	*IEEE Trans. Appl. Supercond.*, Vol. 14 No. 2, pp. 339-344, 2004	2004
3	Conf-04-005-HHH	Performance limits and IR design of a possible LHC luminosity upgrade based on NbTi SC magnet technology	F. Ruggiero, O. Brüning, R. Ostojic, L. Rossi, W. Scandale, T. Taylor (CERN), A. Devred (CEA&CERN)	*Proceedings of the 2004 European Particle Accelerator Conference*, pp. 608-610, 2004	2004
4	Conf-04-020-NED	Status of the Next European Dipole (NED) Activity of the Coordinated Accelerator Research in Europe (CARE) Project	A. Devred (CEA&CERN), B. Baudouy (CEA), D.E. Baynham (CCLRC), T. Boutboul (CERN), S. Canfer (CCLRC), M. Chorowski (WUT), P. Fabbricatore, S. Farinon (INFN-Ge), H. Félice (CEA), P. Fessia (CERN), J. Fydrich (WUT), M. Greco (INFN-Ge), J. Greenhalgh (CCLRC), D. Leroy (CERN), P. Loverige (CCLRC), F. Michel (CEA), L. R. Oberli (CERN), A. den Ouden (TEU), D. Pedrini (INFN-Mi, J. Polinski (WUT), V. Previtali (CERN), L. Quettier, J. M. Rifflet (CEA), J. Rochford (CCLRC), F. Rondeaux (CEA), S. Sanz (CIEMAT), S. Sgobba (CERN), M. Sorbi (INFN-Mi), F. Toral-Fernandez (CIEMAT), R. van Weelderen (CERN), P. Védrine (CEA), O. Vincent-Viry (CERN), G. Volpini (INFN-Mi)	*IEEE Trans. Appl. Supercond.*, Vol. 15 No. 2, pp. 1106-1112, 2005.	2004
5	Con-04-037-NED	Future accelerator magnet needs	A. Devred (CEA&CERN), S. Gourlay (LBNL), A. Yamamoto (KEK)	*IEEE Trans. Appl. Supercond.*, Vol. 15 No. 2, pp. 1192-1199, 2005	2004

Table 2.2 (Cont.): List of papers issued by NED collaborators in 2005.

#	CARE document type and number	Title	Author(s) and Lab(s)	Reference	Date
1	Pub-05-018	Next European Dipole (NED) Activity of the Collaborated Accelerator Research in Europe (CARE) Project, TSQP work package	M. Chorowski (WUT), B. Baudouy (CEA), F. Michel (CEA) J. Polinski (WUT), R. van Weelderen (CERN)	Elektronika, Vol. 2-3/2005, Wydawnictwo Sigma NOT, pp. 77-78	2005
2	Pub-05-017	Termodynamiczna optymalizacja kriostatu do badań cieplnych przewodów z nadprzewodnika Nb_3Sn	M. Chorowski, J. Polinski (WUT)	Elektronika, Vol. 7/2005, Wydawnictwo Sigma NOT, pp. 11-15	2005
3	Conf-05-037-NED	Insulation Development for the Next European Dipole	S J Canfer, E Baynham, R J S Greenhalgh (CCLRC)	Presented at CEC/ICMC'05, Keystone, CO, Aug 29-Sep 2, 2005	2005
4	Pub-05-007	Status of the Next European Dipole (NED) Activity of the Coordinated Accelerator Research in Europe (CARE) Project	A. Devred (CEA&CERN), on behalf of the NED Collaboration	presented at EUCAS'05, Vienna, Austria, Sep 11-15, 2005, submitted to Supercond. Sci. Technol.	2005
5	Pub-05-006	Study of the protection system for the cosine-theta Nb3Sn prototype of the NED dipole	V. Granata, M. Sorbi, G.Volpini, D. Zamborlin (INFN-Mi)	presented at MT'19, Genova, Italy. Sep18-23, 2005, submitted to IEEE Trans. Appl. Supercond.	2005
6	Conf-05-034-NED	Critical current measurements on Niobium-Tin conductors for the NED project	A. den Ouden (TEU), T. Boutboul (CERN), D. Pedrini (INFN-Mi), V. Previstali (CERN), L. Quettier (CEA), G. Volpini (INFN-Mi)	presented at MT'19, Genova, Italy. Sep 18-23, 2005, submitted to IEEE Trans. Appl. Supercond.	2005
7	Pub-05-005	Magnetization measurements of Nb3Sn wires for the Next European Dipole (NED)	M. Greco (INFN-Ge), P. Fabbricatore (INFN-Ge), C. Ferdeghini (INFM, Università di Genova), U. Gambardella (INFN-LNF).	presented at MT'19, Genova, Italy. Sep 18-23, 2005, submitted to IEEE Trans. Appl. Supercond.	2005

Table 2.2 (Cont.): List of papers foreseen to be issued by NED collaborators in 2006.

#	CARE document type and number	Title	Author(s) and Lab(s)	Reference	Date
1		Pressurized He II cryostat for heat transfer measurements on the superconducting cable insulation of the Next European Dipole	WUT&CEA	ICEC 21/ICMC 06	
2		Vacuum Impregnation of compacted glass fabric	G. Ellwood and S. Canfer (CCLRC)	ICEC 21/ICMC 06	
4		Determination of mechanical properties of the individual phases in multifilamentary Nb_3Sn superconducting strands	C. Scheuerlein (CERN), S. Sgobba (CERN), B. Rehmer (BAM), M. Griepentrog (BAM), P. El-Kalassi (CERN)	ICEC 21/ICMC 06	
5		High field superconducting magnet aimed at LHC luminosity upgrade	A. Devred (CEA&CERN), S. Gourlay (LBNL), L. Rossi (CERN) and A. Yamamoto (KEK)	ASC 06	
6		Evaluation of the transfer of heat from the coil of the LHC dipole magnet to Helium II	B. Baudouy (CEA), D. Richter (CERN)	ASC 06	
7		Study of the protection system for Nb_3Sn "slot design" NED dipole	M. Sorbi, G. Volpini, D. Zamborlin (INFN-Mi)	ASC 06	
8		Nano and micro mechanical study of $Nb_3$3Sn wires for the Next European Dipole (NED)	S. Farinon, P. Fabbricatore (INFN-Ge), S. Sgobba, C. Scheuerlein (CERN), A. Devred (CEA&CERN)	ASC 06	
9		Design and optimization of a $\cos\theta$ cross-section for a high field dipole	N. Schwerg, D. Leroy, C. Vollinger (CERN) and A. Devred (CEA&CERN)	ASC 06	
10			M. Greco (INFN-Ge)	ASC 06	
11		Comparison of 2-D magnetic and mechanical designs of selected coil configurations for the Next European Dipole	S. Sanz, F. Toral (CIEMAT), A. Devred (CEA&CERN), P. Vedrine, H. Felice (CEA) J. Rochford, P. Loveridge (CCLRC), P. Fessia, N. Schwerg, F. Regis, C. Vollinger (CERN)	ASC 06	

3 RESOURCES

3.1 Additional Staff Hiring

Table 3.1: Temporary Staff Hiring.

#	Lab	Job Type	Duration	Work subject	Status
1	INFN-Mi	Fellow	6 months	Quench protection computation (supervisor: G. Volpini)	Hired (251104)/Terminated (240505)
2	WUT	Fellow	7 months	Cryostat design (supervisor: M. Chorowski)	Hired (171104)/Terminated (160605
3	WUT	Fellow	7 months	Cryostat design (supervisor: M. Chorowski)	Hired (171104)/Terminated (160605)
4	INFN-Mi	Fellow	6 months	Critical current measurements (supervisor: G. Volpini)	Hired (210206)
5	CEA	Fellow	1 year	Innovative insulation development (supervisor: F. Rondeaux)	Hired (030406)
6	CEA	Postdoc	1 year	Heat transfer measurement (supervisor: B. Baudouy)	July 2006

3.2 Budget

Table 3.2a: Estimated budget for the first 18 months (January 1st 2004 to June 30 2005).

JRA4	Participant (cost model)	Permanent Staff including indirect cost (Euros)	Additional Staff including indirect cost (Euros)	Durable Equipment including indirect cost (Euros)	Consumables and Prototyping including indirect cost (Euros)	Travel including indirect cost (Euros)	Expected costs including indirect cost (Euros)	Direct cost	Subcontract	Indirect cost	Requested funding (Euros)
1	CEA (FC)	199,000	5,000	0	65,000	8,000	277,000	179,000	0	98,000	43,000
10	INFN (AC)	0	15,000	0	7,000	11,000	33,000	27,500	0	5,500	22,000
11	TEU (FC)	36,000	0	0	5,000	4,000	45,000	28,000	0	17,000	18,000
15	WUT (AC)	0	8,500	0	39,500	4,000	52,000	47,495	24,968	4,505	52,000
17	CERN (AC)	0	0	0	400,000	0	400,000	400,000	400,000	0	400,000
20	CCLRC (FC)	135,000	138,000	0	40,000	4,000	317,000	167,000	0	150,000	45,000
	Grand total	**370,000**	**166,500**	**0**	**556,500**	**31,000**	**1,124,000**	**848,995**	**424,968**	**275,005**	**580,000**

Table 3.2b: Executed 2004 budget (January 1st 2004 to December 31st 2004).

JRA4	Participant (cost model)	Permanent Staff including indirect cost (Euros)	Additional Staff including indirect cost (Euros)	Durable Equipment including indirect cost (Euros)	Consumables and Prototyping including indirect cost (Euros)	Travel including indirect cost (Euros)	Expected costs including indirect cost (Euros)	Direct cost	Subcontract	Indirect cost	First received payment (Euros)
1	CEA (FC)	157'537			19'724	10'063	187'324	118'745	0	68'579	32'250
10	INFN (AC)	0	2'784	0	5'258	3'203	11'245	9'370	0	1'874	16'500
11	TEU (FC)	27'578	0	0	1'553	2'093	31'224	17'739	0	13'485	12'490
15	WUT (AC)	0	2'214.68	0	26'936.92	1'430.98	30'582.58	29'859	26'242	723	38'994
17	CERN (AC)	0	0	0	91'906	0	91'906	91'906	91'906	0	300'000
20	CCLRC (FC)	71'151	0	0	11'026	8'130	90'307	48'802	0	41'505	33'750
	Grand total	**256'266**	**4'998**	**0**	**156'404**	**24'920**	**442'588**	**316'421**	**118'148**	**126'166**	**433'984**

Table 3.2c: Requested 2005 budget for the period from January 1st 2005 to June 30 2006.

JRA4	Participant (cost model)	Permanent Staff including indirect cost (Euros)	Additional Staff including indirect cost (Euros)	Durable Equipment including indirect cost (Euros)	Consumables and Prototyping including indirect cost (Euros)	Travel including indirect cost (Euros)	Expected costs including indirect cost (Euros)	Direct cost	Subcontract	Indirect cost	Requested funding (Euros)
1	CEA (FC)	358,116	41,667	0	92,500	24,000	516,283	0	0	516,283	45,000
10	INFN (AC)	0	15,000	0	25,750	7,000	47,750	39,792	0	7,958	47,750
11	TEU (FC)	139,334	0	0	30,000	4,500	173,834	105,693	0	68,141	69,534
15	WUT (AC)	0	6,308	0	12,844	2,584	21,736	18,113	0	3,623	21,736
17	CERN (AC)	0	0	0	350,000	0	350,000	350,000	350,000	0	350,000
20	CCLRC (FC)	274,000	0	0	33,300	16,500	323,800	163,967	0	159,833	26,250
	Grand total	**771,450**	**62,975**	**0**	**544,394**	**54,584**	**1,433,403**	**677,565**	**350,000**	**755,838**	**560,270**

Table 3.2d: Executed 2005 budget (January 1st 2005 to December 31st 2005).

JRA4	Participant (cost model)	Permanent Staff including indirect cost (Euros)	Additional Staff including indirect cost (Euros)	Durable Equipment including indirect cost (Euros)	Consumables and Prototyping including indirect cost (Euros)	Travel including indirect cost (Euros)	Expected costs including indirect cost (Euros)	Direct cost	Subcontract	Indirect cost	Second received payment (Euros)
1	CEA (FC)	210'473	0	140	4'692	12'936	228'241	138'598	0	89'643	36'000
10	INFN (AC)	0	11'976	0	0	733	12'709	10'591	0	2'118	
11	TEU (FC)	90'474	0	0	0	1'782	92'256	49'184	0	43'072	36'902
15	WUT (AC)	0	11'034	0	7'655	407	19'096	15'913	0	3'183	11'562
17	CERN (AC)	0	0	0	44'625	0	44'625	44'625	44'625	0	
20	CCLRC (FC)	177'549	0	0	25'573	12'673	215'795	81'647	0	95'902	36'280
	Grand total	**478'496**	**23'010**	**140**	**82'545**	**28'531**	**612'722**	**340'558**	**44'625**	**233'918**	**120'744**

Table 3.2e: Requested 2006 budget for the period from January 1st 2006 to June 30 2007.

JRA4	Participant (cost model)	Permanent Staff direct cost ONLY (Euros)	Additional Staff direct cost ONLY (Euros)	Durable Equipment direct cost ONLY (Euros)	Consumables and Prototyping direct cost ONLY (Euros)	Travel direct cost ONLY (Euros)	All direct cost	Subcontract	Indirect cost	Expected costs including indirect cost (Euros)	Requested funding (Euros)
1	CEA (FC)	98'857	96'642	0	37'500	20'000	252'999	0	152'668	405'667	31'755
10	INFN (AC)	0	7'000	0	15'700	4'000	26'700	0	5'340	32'040	32'000
11	TEU (FC)	62'563	0	0	15'000	3'000	80'563	0	56'817	137'380	54'700
15	WUT (AC)	0	0	0	0	5'376	5'376	0	1'075	6'451	5'444
17	CERN (AC)	0	0	0	465'000	0	465'000	465'000	0	465'000	465'000
20	CCLRC (FC)	99'000	0	0	9'300	5'300	113'600	0	57'717	171'317	24'012
	Grand total	**260'420**	**103'642**	**0**	**542'500**	**37'676**	**944'238**	**465'000**	**273'617**	**1'217'855**	**612'911**

4 STATUS OF THE WORK

4.1 Work Package 1: Management and Communication (M&C)

2004 Summary

The NED Steering Committee (SC) has met four times (8 January, 25 March, 8 July and 29 October), while the NED External Scientific Advisory Committee (ESAC) has met once (24 March) and has produced a report.

The NED work breakdown structure has been implemented by E. Deluncige (CERN) into the CERN Engineering Data and Management Service (EDMS):
https://edms.cern.ch
under CERN/AT Department/CARE. This service is used to release, circulate, track and store documents. Access is restricted to members of the NED collaboration (as identified in EDMS 547908).

A dedicated web page has been set up by A. den Ouden (TEU):
http://lt.tnw.utwente.nl/project.php?projectid=9
The webpage is updated regularly with all information pertinent to the NED JRA and is accessible by the general public.

Detailed implementation plans of the three technical Work Packages (Thermal Studies and Quench Protection or TSQP, Conductor Development or CD, and Insulation Development and Implementation or IDI) have been established and launched and all collaborators have started their activities. In addition, the Activity scope has been extended, thanks to the setting up of a Working Group on Magnet Design and Optimization (WGMDO), supported by CCLRC and by additional resources from CEA, CERN and CIEMAT, a CARE Associated Laboratory who has decided to join the NED collaboration.

Three status reports have been produced

- 2nd quarter of 2004: EDMS 548027
- 3rd quarter of 2004: EDMS 548028
- Yearly report for 2004: EDMS 548030V4

2005 Summary

The NED Steering Committee (SC) has met four times: 20 January and 14 April at CERN, 7 July at WUT and 24 November at CERN.

A total of 7 papers (6 contributed and 1 invited) have been presented at international conferences pertinent to NED. Four of them have been published in peer-reviewed journals.

Three status reports have been produced

- 1st quarter of 2005: EDMS 588774V2
- 2nd quarter of 2005: EDMS 673326V2
- Yearly report for 2005: EDMS 689720V3

2006 Summary

The NED Steering Committee (SC) has met one time: 23 February at CERN and the next meeting is scheduled at CIEMAT on June 1st.

A total of 10 papers (9 contributed and 1 invited) are foreseen. Six of them will be published in a peer-reviewed journal.

One status reports has been produced

- 1st quarter of 2006: EDMS 721734V3

4.1.1 Activity Coordination

The NED JRA is coordinated by A. Devred (CEA&CERN), helped by A. den Ouden (TEU).

The following actions have been carried out and/or are foreseen

- ✓ 19–21 November 2003: participation of A. Devred (CEA&CERN) and A. den Ouden (TEU) to CARE Kick Off meeting at CERN
- ✓ 13 January 2004: visit of A. Devred (CEA&CERN) to INFN-Ge
- ✓ 16 January 2004: visit of P. Védrine (CEA) and A. Devred (CEA&CERN) to CIEMAT
- ✓ 27 January 2004: visit of A. Devred (CEA&CERN) to TEU
- ✓ 13 February 2004: A. Devred (CEA&CERN), P. Lebrun and L. Rossi (CERN) to INFN-Mi
- ✓ 23–24 February 2004: participation of A. Devred (CEA&CERN) to CARE Steering Committee and Dissemination Board meetings in Paris, France
- ✓ 19 March 2004: visit of F. Rondeaux and P. Védrine (CEA), A. Devred (CEA&CERN) to CCLRC
- ✓ 22–24 March 2004: participation to Workshop on Accelerator Magnets Superconductor (WAMS) organized within the framework of AMT Work Package of HHH Network Activity
- ✓ 13 April 2004: visit of A. Devred (CEA&CERN) and M. Pojer (CERN) to INFN-Ge
- ✓ 2–3 June 2004: visit of B. Baudouy and F. Michel (CEA), A. Devred (CEA&CERN), R. Van Weelderen (CERN) to WUT
- ✓ 24–25 June 2004: participation of A. Devred (CEA&CERN) and A.den Ouden (TEU) to CARE Steering Committee and Dissemination Board meetings in Warsaw, Poland
- ✓ 24 August 2004: visit of M. Chorowski (WUT) to CEA/Saclay
- ✓ 2–5 November 2004: participation of A. Devred (CEA&CERN) to CARE general meeting at DESY
- ✓ 11-12 November 2004: participation of a number of NED collaborators to the HHH/AMT annual meeting at CERN.
- ✓ 3-4 March 2005: participation of a number of NED collaborators to the HHH meeting on Beam-Generated Heat Deposition and Quench Levels in LHC Magnets organised at CERN.

- ✓ 22-23 March 2005: participation of a number of NED collaborators to the HHH/AMT meeting on Insulation & Impregnation Technique organised at CERN
- ✓ 5-6 September 2005: participation of A. Devred /CEA&CERN) to CARE Steering Committee and Dissemination Board meetings in Paris
- ✓ 22-25 November 2005: participation of a number of NED collaborators to CARE general meeting at CERN
- ✓ 23 November 2005: participation of a number of NED collaborators to the HHH/AMT annual meeting at CERN
- ✓ 24 November 2005: participation of A. Devred to CARE Governing Board and Dissemination meetings at CERN
- ✓ 26 January 2006: visit of A. Devred to INFN-Mi
- ✓ 3-6 April 2006: large participation of NED collaborators to WAMDO organized by HHH/AMT at CERN
- ✓ 11 April 2006: participation of A. Devred to CARE Steering Committee meeting at LPNHE (Paris)
- ✓ 27 April 2006: visit of A. Devred to INFN-Ge
- ⇒ 31 May–1 June 2006: visit of A. Devred to CIEMAT
- ⇒ next CARE Steering Committee meeting: 13-14 September at CERN
- ⇒ next CARE general meeting: 15-17 November at Frascati

4.1.2 Meetings

4.1.2.1 Steering Committee Meetings

The oversight of the NED JRA is ensured by a Steering Committee (SC) made up of

- E. Baynham (CCLRC)
- A. Devred (CEA&CERN), Chairman
- L. Oberli (CERN)*
- J.M. Rifflet (CEA)
- G. Volpini (INFN-Mi)
- A. den Ouden (TEU), Secretary

* L. Oberli has taken over D. Leroy's responsibility since 30 June 2005.

SC meetings are held every three months. Available copies of the presentations and minutes of the meetings have been loaded into EDMS and are posted on the NED website.

The following actions have been carried out and/or are foreseen

- ✓ 8 January 2004: meeting at CERN
  participants: E. Baynham (CCLRC), A. Devred (CEA&CERN), D. Leroy, L. Oberli and O. Vincent-Viry (CERN), P. Fabbricatore (INFN-Ge), G. Volpini (INFN-Mi), A. den Ouden (TEU)
  special guests: L. Rossi (CERN), H. ten Kate (CERN&TEU)
  agenda+talks: EDMS 548032; also available on NED website
- ✓ 25 March 2004: meeting at CERN
  participants: B. Baudouy and J.M. Rifflet (CEA), A. Devred (CEA&CERN), D. Leroy and R. van Weldeeren (CERN), F. Toral (CIEMAT), G. Volpini (INFN-Mi), E. Baynham and S. Canfer (CCLRC), A. den Ouden (TEU)

special guests: A. Yamamoto (KEK), S. Gourlay (LBNL)
agenda+talks: EDMS 548033; also available on NED website

- ✓ 8 July 2004: meeting at CERN
participants: E. Baynham and S. Canfer (CCLRC), A. Devred (CEA&CERN), F. Rondeaux and P. Védrine (CEA), T. Boutboul, D. Leroy, L. Oberli, V. Previtali, O. Vincent-Viry, R. van Weldeeren (CERN), P. Fabbricatore and S. Farinon (INFN-Ge), M. Sorbi (INFN-Mi), A. den Ouden (TEU)
special guests: –
agenda+talks: EDMS 548034; also available on NED website
- ✓ 29 October 2004: meeting at CEA/Saclay
participants: S. Canfer (CCLRC), A. Devred (CEA&CERN), H. Felice, L. Quettier, J.M. Rifflet, F. Rondeaux, P. Védrine (CEA), T. Boutboul, D. Leroy, L. Oberli, V. Previtali, R. van Weldeeren (CERN), M. Greco (INFN-Ge), D. Pedrini, M. Sorbi, G. Volpini (INFN-Mi), A. den Ouden (TEU), M. Chorowski, J. Polinski (WUT)
special guests: R. Aleksan (CPPM), P. Debu, M. Durante (CEA), B. Adamowicz (Kryosystem)
agenda+talks: 548035; also available on NED website
- ✓ 20 January 2005: meeting at CERN
participants: S. Canfer, E. Baynham (CCLRC), A. Devred (CEA&CERN), F. Michel, J.M. Rifflet (CEA), T. Boutboul, P. Fessia, D. Leroy, L Oberli, D. Richter, W. Scandale, C. Scheuerlein, N. Schwerg, S Sgobba (CERN), P. Fabbricatore, S. Farinon, M. Greco (INFN-Ge), F. Broggi, V. Granata, M. Sorbi, G. Volpini (INFN-Mi), A. den Ouden (TEU)
agenda+talks: 548036; also available on NED website
- ✓ 14 April 2005: meeting at CERN
participants: S. Canfer, E. Baynham (CCLRC), A. Devred (CEA&CERN), T. Boutboul, L Oberli, C. Scheuerlein, R. Schmidt, S Sgobba, R. Van Weldeeren (CERN), F. Toral (CIEMAT), S. Farinon, M. Greco (INFN-Ge), V. Granata, M. Sorbi, G. Volpini (INFN-Mi), A. den Ouden (TEU), S. Petrowicz, M. Chorowski (WUT)
agenda+talks: 575731
- ✓ 7 July 2005: meeting at WUT
participants: S. Canfer (CCLRC), A. Devred (CEA&CERN), F. Michel, J.M. Rifflet (CEA), T. Boutboul, D. Leroy, L Oberli, S Sgobba, R. Van Weldeeren (CERN), M. Greco (INFN-Ge), M. Sorbi, G. Volpini (INFN-Mi), A. den Ouden (TEU), S. Petrowicz, M. Chorowski (WUT)
agenda+talks: 604114
- ✓ 24 November 2005: meeting at CERN
participants: E. Baynham, S. Canfer, G. Ellwood (CCLRC), A. Devred (CEA&CERN), B. Baudouy, P. Védrine (CEA), T. Boutboul, A. Desirelli, P. Fessia, D. Leroy, L Oberli, M. Pojer, F. Regis, D. Richter, V. Previtali, C. Scheuerlein, S Sgobba, R. Van Weldeeren (CERN), M. Greco, P. Fabbricatore, S. Farinon (INFN-Ge), F. Broggi, M. Sorbi, G. Volpini (INFN-Mi), A. den Ouden (TEU), M. Chorowski (WUT)
agenda+talks: 680728
- ✓ 23 February 2006: meeting at CERN
participants: E. Baynham, S. Canfer, G. Ellwood (CCLRC), A. Devred (CEA&CERN), J.M. Rifflet (CEA), T. Boutboul, S. Illie, J.P. Koutchouk, D. Leroy, L Oberli, D. Richter, V. Previtali, C. Scheuerlein, S Sgobba (CERN),

M. Greco, S. Farinon (INFN-Ge), F. Broggi, M. Sorbi, G. Volpini (INFN-Mi), J. Fydrych. Chorowski (WUT)
agenda+talks: 700477

⇒ next meeting: 1st June 2006 at CIEMAT
participants: S. Canfer, G. Ellwood (CCLRC), A. Devred (CEA&CERN), M. Aguilar, L. Garcia Tabares, Fernando Toral (CIEMAT), T. Boutboul, L.-Oberli, (CERN), M. Greco (INFN-Ge), G. Volpini (INFN-Mi), A. den Ouden (TEU)

⇒ following meeting: 12 September at CERN

4.1.2.2 External Scientific Advisory Committee Meetings

The NED JRA Coordinator is assisted by an External Scientific Advisory Committee (ESAC). The charges and composition of the committee are defined in EDMS 548039. The committee is made up of

- J.L. Duchateau (CEA)
- P. Lebrun (CERN)
- L. Rossi (CERN)
- R.M. Scanlan (formerly LBNL, retired)
- J.B. Strait (FNAL), Chairman
- H.H.J. ten Kate (CERN&TEU)

The following actions have been carried out and/or are foreseen

✓ 24 March 2004: first meeting at CERN
agenda: EDMS 548039; presentations available on NED website

✓ 29 March 2004: first ESAC report (EDMS 548041)
agenda+talks: 548035; also available on NED website

⇒ next meeting: 21 November 2006 at Frascati

4.2 Work Package 2: Thermal Studies and Quench Protection (TSQP)

Work Package 2 includes two main Tasks:

- development and operation of a test facility to study and characterize heat transfer to helium through Nb_3Sn conductor insulation

(involving CEA and WUT, under the supervision of B. Baudouy, CEA)

- quench protection computation

(carried out by INFN-Mi, Task Leader: G. Volpini)

2004 Summary

The first part of the Task on heat transfer measurements was to design and build and new He-II, double-bath cryostat. CEA wrote detailed specifications that were handed out to WUT in June 2004. WUT performed a call for tender in the Summer of 2004 and selected Kryosystem in Poland to manufacture the cryostat. Work was started in the Fall of 2005 and a Production Readiness Review was held at Saclay on 29 October 2004.

After completing a literature survey of relevant material properties (EDMS 555753), INFN-Mi has carried out detailed quench computations based on the 88-mm-aperture, cosθ-layer design chosen as Reference Design V1 for NED in conclusion of Task 3.2. The computations study the influence of various parameters such as: magnet length (1, 5 and 10 m), operating current (15, 22 and 29 kA), value of external dump resistor (15, 25, 35 and 45 mΩ), quench detection delay (30, 40 and 50 ms) and quench protection heater length. They are carried out using two independent codes: QLASA, originally developed at INFN-Mi for solenoids and subsequently adapted to accelerator magnet coil configuration by means of suitable geometric approximations, and QUABER, a collection of scripts written in MAST and run with the commercial interface SABER that was developed at CERN to study LHC magnet protection. An interim report (EDMS 555756) summarizes the results obtained for a 1-m-long and a 5-m-long magnet.

2005 Summary

Some delays have been encountered in the manufacturing of the cryostat and of the enclosed heat exchanger. Preliminary reception tests were held at WUT during the 3rd week of April, which revealed some problems. The problems were fixed in May-June 2005 and another round of tests was carried out at WUT on 6-8 July 2005. These tests included thermal and leak tests in liquid helium environment at 4.2 K and were deemed successful. The cryostat was then transported by road to CEA/Saclay, where it arrived on 20 September 2005. It is now being prepared for tests in He II and commissioning. The first measurements are expected to take place in early 2006.

In parallel, CERN is carrying out a detailed analysis of existing cold test data from LHC magnet models and prototypes so as to verify whether or not the high heat-transfer coefficients measured at CEA on coil mock-ups are also observed in actual magnets. The analysis is based on a review of quench data and of AC-loss measurement as a function of ramp rate and will be compared to similar work carried out at FNAL on LHC Insertion Region quadrupole magnet model. It is expected to be completed by December 2005.

CERN has also undertaken a review of cooling modes and has come to the preliminary conclusion that the most efficient one remains pressurized superfluid helium as chosen for the

LHC. The heat removal capabilities of pressurized superfluid helium are very well suited to the magnet designs under consideration. The benefit from enhanced Nb_3Sn critical current is as well an argument. As a result, it is likely that NED-like magnets will have to be operated at 1.9 K. The effort on magnet cooling optimization will be pursued within the framework of an existing collaboration between CERN and Wroclaw University of Technology.

Quench computations have been carried out for a 10-m-long magnet relying on the reference 88-mm-aperture, cosθ, layer design. They confirm the results already obtained for smaller lengths: the hot spot temperature always remains below 300 K and the maximum voltage can be limited to 800 V by an adequate choice of dump resistor. This implies that that such type of magnet is safe to operate, thanks mainly to the choice of strand and cable parameters made early on. In addition, the two softwares that have been used (QLASA and QUABER) appear to yield similar results. To wrap up this Task, computations have been run on a more challenging 160-mm-aperture, cosθ slot design for a length of 5 m. The magnet protection, albeit feasible, appears more difficult than for the conventional cosθ layer design and requires efficient quench protection heaters in every slot. The final report on the protection of the cosθ layer designs was completed on 8 November 2005 (EDMS 683013) and is presently under peer review. The additional work on the cosθ slot design will be written as an Appendix. A summary paper on this Task was presented at the Magnet Technology Conference (MT'19) in Genova.

2006 Summary

The first cool down of the cryostat was carried out in February. A temperature of 4.2 K has been reached in 7 hours as it was expected. No problem in instrumentation nor vacuum has been encountered. One can mention that the time to reach the temperature of liquid helium is a proof of the excellent thermal insulation.
The pumping system and the feeding tube has been tested. A temperature of 1.5 K in the He-II pressurized bath (HeIIp) has been reached (TT4) by pumping in the He-II saturated bath (HE-IIs). Only one problem occurred: the liquid level meter in the saturated bath is not functioning properly and prevents to test the liquid level regulation system in the saturated cryostat and, therefore, the temperature regulation system in the pressurized bath. Nevertheless, a pseudo regulation at 2 K within 10 mK in the He-IIp bath with 1.9 K in the He-IIs bath (TT2) has been achieved.
Consequently to the liquid level malfunctioning, both meters (the 4 K and 2 K) have been tested several times to identify the problem. The problem has been identified and is not solved for the time being but meanwhile a new level meter has been ordered as a back up. The new liquid level is under test and will be placed shortly in the cryostat.
This test offered the opportunity to test the acquisition system (hardware and software) of the cryostat monitoring and control system. No problem was encountered. The hardware of the acquisition system for the measurements system has been also tested with no problem.
Finally, the software for the measurements system has been completed and tested at room temperature. No problem either.
To conclude, the tests at low temperature show that the cryostat meet all the requirements in terms of general functioning and another test is needed to perform the thermal qualification of the heat exchanger and the qualification of the JT valve.

4.2.1 TSQP WP coordination

As already mentioned, the TSQP Work Package is articulated around two main tasks: Heat Transfer Measurements (2.2) and Quench Computation (2.3). Task 2.2 is coordinated by B. Baudouy (CEA), while Taks 2.3 is coordinated by G. Volpini (INFN-Mi). The Task Leaders report to the NED Steering Committee and, ultimately, to the NED/JRA Coordinator.

4.2.2 Heat Transfer Measurements

The following actions have been carried out and/or are foreseen

4.2.2.1 Drafting of Test Facility Specifications

- ✓ 28 January 2004: preparatory meeting at CEA/Saclay
  participants: B. Baudouy, P. Chesny, B. Hervieu, F. Michel and J.M. Rifflet (CEA), A. Devred (CEA&CERN)
- ✓ 27 February 2004: programme proposal issued by B. Baudouy (CEA; EDMS 548123)
- ✓ March 2004: review of programme proposal by P. Lebrun and D. Leroy (CERN) and approbation by SC meeting
- ✓ 4 May 2004: cryostat specification issued by B. Baudouy, B. Hervieu and F. Michel (CEA; EDMS 548129V1)
- ✓ May 2004: specification submitted for review to P. Lebrun and R. Van Weelderen (CERN) and M. Chorowski (WUT)
- ✓ 8 June 2004: final cryostat specification issued by B. Baudouy, B. Hervieu and F. Michel (CEA; EDMS 548129V2)

Sub-Task completed

4.2.2.2 Cryostat Design and Fabrication

- ✓ 3 June 2004: preparatory visit to Kryosystem (Poland)
  participants: B. Baudouy, F. Michel (CEA), A. Devred (CEA&CERN) R. van Weelderen (CERN), M. Chorowski, J. Fydrych and J. Polinski (WUT), B. Adamowicz, G. Michalski and G. Strychalski (Kryosystem)
- ✓ July 2004: start of technical design at WUT
- ✓ July 2004: start of tendering procedure
- ✓ 10 August 2004: redefinition of WUT budget allocation
- ✓ August 2004: contract attribution to Kryosystem
- ✓ 29 Ooctober 2004: Production Readiness Review at CEA Saclay
  participants: B. Baudouy, F. Michel (CEA), R. van Weelderen (CERN), M. Chorowski, J. Polinski (WUT), B. Adamowicz (Kryosystem)
  report: EDMS 548154)
- ✓ 17 November 2004: hiring of Grzegorz Michalski and Maciej Matkowski at WUT (additional staff; till 30 June 2005)
- ✓ Early April 2005: completion of manufacturing
- ✓ 20-22 April 2005: preliminary reception tests at WUT, in
  participants: B. Baudouy and F. Michel (CEA) and of M. Chorowski and J. Polinski (WUT)
  Test report: EDMS 587176
- ✓ 2 May 2005: set of recommendations issued by B. Baudouy, F. Michel (CEA) and A. Devred (CEA&CERN) – EDMS 587176

- ✓ 6 May 2005: report on mechanical design study issued by M. Chorowski and J. Polinksi (WUT) – EDMS 592247
- ✓ 12 May 2005: first status report on repairs issued by M. Chorowski and J. Polinksi (WUT) – EDMS 592246
- ✓ 19 May 2005: Comments on status report issued by B. Baudouy and F.Michel (CEA) – EDMS 593633
- ✓ 3 June 2005: second status report on repairs issued by M. Chorowski and J. Polinksi (WUT) – EDMS 598854
- ✓ 3 June 2005: second version of report on mechanical design study issued by M. Chorowski and J. Polinksi (WUT) – EDMS 592247V2
- ✓ 6-8 July 2005: second round of reception tests at WUT participants: B. Baudouy and F. Michel (CEA) and of M. Chorowski and J. Polinski (WUT)
  Test report: EDMS 609237
- ✓ 20 September 2005: reception of cryostat at CEA

Sub-Task completed

4.2.2.3 Cryogenic Module Design and Fabrication

- ✓ 22 June 2004: design specifications issued by B. Baudouy and F. Michel (CEA; EDMS 548139, based on design study reviewed in EDMS 548137)
- ✓ 1st July 2004: call for tender issued by F. Michel (CEA)
- ✓ 15 July 2004: reception of answers to call for tender
- ✓ 17 September 2004: purchase requisition to be issued by F. Michel (CEA)
- ✓ 10 October 2004: contract awarded to Kryosystem.
- ✓ Early April 2005: completion of manufacturing

Sub-Task completed

4.2.2.4 Facility Integration and Qualification

- ✓ September 2005 vacuum and pressure test
- ✓ September 2005: leak test
- ✓ October-November 2005: instrumentation, wiring and insulation
- ✓ December 2005: external cabling
- ✓ February 2006: first successful cool down test down to 1.5 K, revealing problem with liquid level meter
- ⇒ June 2006: retest in He II commissioning

4.2.2.5 Measurements and Analyses

Not started

4.2.3 Quench Protection Computation

The following actions have been carried out and/or are foreseen

- ✓ 5 March 2004: draft computation programme issued by M. Sorbi and G. Volpini (INFN-Mi; EDMS 555747)
- ✓ March 2004 SC meeting: discussion of computation programme
- ✓ April–June 2004: compilation of material properties (EDMS 555753)
- ✓ June-October 2004: first computations on Reference Design V1 (88-mm-aperture, cosθ, layer design)
- ✓ November-December 2004: extended computations on Reference Design V1

- ✓ 25 November 2004: hiring of Valeria Granata by INFN-Mi (additional staff for 6 months)
- ✓ 3 February 2005: first version of interim report (EDMS 555756; EU milestone)
  authors: V. Granata, M. Sorbi, G. Volpini, D. Zamborlin (INFN-Mi)
- ✓ 13 April 2005: second version of interim report (EDMS 555756V2)
  authors: V. Granata, M. Sorbi, G. Volpini, D. Zamborlin (INFN-Mi)
- ✓ 24 May 2005: termination of Valeria Granata
- ✓ 29 September 2005: first version of MT19 paper
- ✓ 8 November 2005: first version of final report (INFN-Mi); EDMS 683013, EU deliverable
- ✓ 6 December 2005: final version of MT19 paper issued by M. Sorbi (EDMS 688572)
- ✓ 13 February 2006: second version of final report (INFN-Mi); EDMS 683013 V2, EU deliverable
- ✓ 24 February 2006: third version of final report (INFN-Mi); EDMS 683013 V3, EU deliverable

Sub-Task completed

Table 4.2a: Status of the lowest Sub-Tasks level in the TSQP WP (as of 30 April 2006).

WBS #	Title	Original begin date (Annex 1)	Original end date (Annex 1)	Estimated Status	Revised end date
2.1	TSQP WP Coordination				
2.2	Heat Transfer Measurements				
2.2.1	Drafting of Test Facility Specifications	1 January 2004	31 March 2004	Completed	8 June 2004
2.2.2	Cryostat Design and Fabrication	1 April 2004	31 Dec. 2004	Completed	8 July 2005
2.2.3	Cryogenic Module Design and Fabrication	1 April 2004	31 Dec. 2004	Completed	8 July 2005
2.2.4	Facility Integration and Qualification	1 January 2005	31 March 2005	80 %	30 June 2006
2.2.5	Measurements and Analyses	1 April 2005	31 Dec. 2006	Not started	30 June 2007
2.3	Quench Protection Computation	1 April 2004	30 June 2005	99 %	31 December 2005

Table 4.2b: Status with respect to the milestones and deliverables due in the TSQP WP (as of 30 April 2006).

WBS #	Title	Responsible Lab(s)	Due date in Annex 1	Status	Revised delivery date
2.2.4	Report on Heat Transfer Facility Commissioning (deliverable)	CEA and WUT	1 April 2005	Not started	30 June 2006
2.2.5	Interim Report on Heat Transfer Measurements (milestone)	CEA	31 December 2005	Not started	31 December 2006
2.2.5	Final Report on Heat Transfer Measurements (deliverable)	CEA	31 December 2006	Not started	30 June 2007
2.3	Interim Report on Quench Protection (milestone)	INFN-Mi	31 December 2004	Completed	13 April 2005
2.3	Final Report on Quench Protection (deliverable)	INFN-Mi	30 June 2005	Completed	24 February 2006

4.3 Work Package 3: Conductor Development (CD)

Work Package 3 includes three main Tasks:

- conductor development
(under CERN supervision, Task Leader: L. Oberli)
- conductor characterization
(involving CEA, CERN, INFN-Mi, INFN-Ge and TEU, under the supervision of A. den Ouden, TEU)
- FE wire model to simulate cabling effects
(involving CERN and INFN-Ge and TEU, under the supervision of S. Farinon, INFN-Ge)

The CD Work Package is the core of the program and will absorb about 70% of the EU funding.

2004 Summary

CERN has investigated two different magnetic designs, referred to as $\cos\theta$ layer design and $\cos\theta$ block design and has considered 3 apertures: 88 mm, 130 mm and 160 mm. These investigations, described in a report (EDMS 555826), led to the definition of wire and cable parameters used as a basis for conductor specifications. The 88-mm-aperture, $\cos\theta$ layer design has been chosen as a baseline for NED (Reference Design V1 as defined in EDMS 555825). One particularity of this design is that it calls for a wide cable (26 mm) made up of 40 stands of large diameter (1.25 mm) and high critical currents (≥ 1636 A at 4.2 K and 818 A at 15 T and 4.2 K). This reliance on a large conductor and a large transport current is a deliberate choice that differentiates the NED program from what is done in the USA where the emphasis is put on achieving the highest possible critical current density and on adapting conductor and magnet design so as to optimize performances with respect to this parameter.

After writing comprehensive wire and cable specifications and a detailed technical questionnaire (EDMS 475443), CERN has issued a call for tender in June 2004 and has selected in November 2004 Alstom/MSA, in France, and ShapeMetal Innovation (SMI), in the Netherlands, to be the main wire and cable contractors. After discussion with CERN, the two companies have established development plans made up of two R&D steps (referred to as STEP1 and STEP2) followed by final production. For Alstom/MSA, which promotes the "Enhanced Internal Tin" process, STEP1 is devoted to a Taguchi-type plan to study the influence of salient parameters on workability and performances, while STEP2 will be devoted to a tuning of critical current density. For SMI, which promotes the "Powder In Tube" process, STEP1 is devoted to iterations on an existing, 1-mm-diameter, wire design, which has reached a non-copper critical current density of 2500 A/mm^2 at 4.2 K and 12 T, while STEP2 will be devoted to a scale-up to larger-size billets. The results of STEP1 are expected in the Fall of 2005, while those of STEP2 are expected in the Summer of 2006. Both companies have started the procurements of raw materials.

A Working Group on Conductor Characterization (WGCC) made up of representatives from CEA, CERN, INFN-Mi, INFN-Ge and chaired by A. den Ouden (TEU) has been set up in the Spring of 2004 to oversee wire I_C and magnetization measurements. The Working Group has initiated a cross-calibration of the various test facilities available to perform these measurements. In parallel, INFN-Ge has undertaken a series of magnetization measurements with different types of apparatus to evaluate their respective pertinence, including a SQUID magnetometer at INFM, Genova, a Vibrating Sample Magnetometer (VSM) at LNF and an

AC-susceptibility magnetometer available in house. These measurements were carried out either as a function of field, to assess effective filament diameter and the amplitude of flux jumps, or as a function of temperature, to study the nature and size of the various superconducting phases.

An effort has been launched by INFN-Ge to develop a FE mechanical model of un-reacted wires so as to simulate the effects of cabling and derive optimum billet layout. This model was first applied to an old, ITER-type, internal-tin wire design produced by Alstom/MSA (EDMS 548087). However, to be accurate, it requires a detailed knowledge of the properties of the materials that make up the wire in their cold work state at the end of drawing. CERN has undertaken a literature survey of these properties and has launched a series of nano-hardness and micro-hardness measurements on cross-cuts of the Alstom/MSA ITER-type wire to check and complement these data. The nano-hardness measurements are sub-contracted to a laboratory of Ecole d'Ingénieurs de l'Arc Jurassien (EIAJ, located in Le Locle, Switzerland) while the micro-hardness measurements are performed in house. Two reports (EDMS 548100 for EIAJ and EDMS 548116 for CERN) summarize these measurements.

2005 Summary

Both industrial sub-contractors have received their raw materials and have started assembling and transforming STEP1 billets.
During STEP1, SMI has tried to increase the non-copper critical current density of the 192 filament Powder In Tube strand to a value above 2500 A/mm^2 at 12 T. SMI has produced 2 billets using a tantalum barrier around the niobium tube of each filament and 2 billets (called B201 and B205) with a modified powder composition without using a tantalum barrier. The drawing to a diameter of 1 mm of the 2 billets using a Ta barrier was not successful due to a large number of breakages attributed to a poor quality of the Ta barrier. The 2 other billets B201 and B205 were drawn without breakage to a diameter of 1 mm and two unit lengths of 327 m and 320 m were delivered to CERN. A critical current density around 2350 A/mm^2 at 12 T was measured on the billet B201, much lower than expected due to Sn leakage occurring at the melting point of Sn. A piece length of 20 m of another billet called B179 was delivered to CERN. On a sample of the billet B179, a critical current density of 2584 A/mm^2 at 12 T was obtained by SMI.
CERN has carried out an extensive program to characterize the strands. A RRR value of 220 was measured on a sample of the billet B179 above the specified NED value. RRR measurements performed on samples of the billet B201 have confirmed the Sn leakage in the copper matrix. The Sn leakage is a consequence of the rupture of the Nb tube. Metallographic strand cross-sections of the reacted strand have permitted to observe a burst Nb tube by optical microscopy, which explains the low critical current density. Same test will be performed on the billet B205 as Sn leakage was also reported by SMI, even if the free Sn content in the powder was decreased compared to the Sn content used in the powder of the billet B201. CERN has also investigated the strand behaviour under heavy deformation to evaluate if the strands are indeed capable to sustain the cabling. Samples of the 2 billets B179 and B201 were rolled down at CERN to flatten the strand from 1 mm to 0.85, 0.75 and 0.65 mm. The filament layout was observed by optical metallography of the cross-section of the samples. Whereas the filament layout of the billet B179 rolled to 0.75 mm was severely deformed showing shear fracture planes crossing the filaments, the filament layout of the billet B201 was able to sustain the high unidirectional deformation. More extensive investigations will be launched on samples from billets B179 and B205 to understand how the internal filament layout sustains the deformation by rolling. For the next period, the effort will

be focused on the qualification of the final design by using filaments identical to the billet B179 with equal powder composition and with more copper around the filaments as for the billet B201.
For STEP1, Alstom/MSA has launched 5 types of strand in fabrication following an internal tin process. The different layouts were discussed with CERN with the aim to determine the optimum design to get a good workability and a high critical current. Alstom/MSA has encountered few problems in the preparation of the Sn rods used in billet assembly and in the extrusion of the monofilament billets. Solutions have been found and CERN has contributed by performing quality assurance tests on the Sn rods to verify the suitability of the process and acid cleaning of the Nb bars. All intermediate billets have been assembled and drawn. Only one type of intermediate billets with a central Sn core was successfully drawn without breakages to restacked dimension. Alstom/MSA has investigated the possible reasons and has decided in agreement with CERN to produce two additional intermediate billets with a modified process. A revised plan for STEP2 is in discussion with CERN to improve the manufacturing process followed for STEP1 and to develop alternative manufacturing process for intermediate billets. The first results of STEP1 are expected in January 2006, while those of STEP2 are expected in the Summer of 2006.

The cross-calibration program launched by the Working Group on Conductor Characterization has proven more difficult than anticipated. Three rounds of “virgin” test wires have been circulated among the various laboratories and have pointed out a number of problems and discrepancies in sample preparation and instrumentation as well as in measurement procedures. The first round included a reference, LHC-type, NbTi wire, and two Nb_3Sn wires: one 1.26-mm-diameter ECN PIT wire provided by TEU and one 0.83-mm-diameter EM Internal Tin wire provided by INFN-Mi (the EM wire samples were either “virgin” or extracted from a Rutherford-type cable). The second round relied again the 1.26-mm-diameter ECN PIT wire, while the third round included a 1-mm-diameter, SMI, ternary $Nb(Ta)_3Sn$, PIT wire, also provided by TEU. INFN-Mi and TEU have now achieved a good convergence on I_C measurements (results for the SMIT PIT wire samples agree within 2%) while CEA is still in the process of upgrading its test facility. The third round also included “virgin” and “deformed” samples of the 1.26-mm-diameter ECN PIT wire to evaluate cabling degradation (the wire was rolled down at CERN with diameter reductions of 0.30, 0.35, 0.40 and 0.45 mm, but only the samples with a 0.35-mm diameter reduction were tested). The INFN-Mi and TEU measurements of these samples show a larger dispersion (5 to 7%) than for the SMI PIT wire measurements (which may be due to heterogeneity in the wire itself); the I_C degradation between deformed and virgin samples is estimated around 40%. A status report on the cross-calibration program was presented at the Magnet Technology Conference (MT’19) in Genova (EDMS 690009).

INFN-Ge has carried out detailed investigations of the 1.26-mm-diameter ECN PIT wire mentioned above to develop his characterization techniques. Magnetization measurements performed as a function of temperature (in a 1-mT parallel field) with a SQUID magnetometer clearly show two transitions: one for a temperature of ~17.4 K, corresponding to Nb_3Sn, and one around 9.2 K, corresponding to pure Nb. The origin of these two transitions can be readily understood when considering the wire structure: it is drawn down from a billet made up from thick-walled niobium tubes, arranged in a pure copper matrix and stuffed with a mixture of $NbSn_2$, Cu and Sn powders. During heat treatment, the powder mixture reacts with the Nb tubes and precipitate Nb_3Sn layers, which grow from the inner to the outer radii of the tubes. The heat treatment is usually optimized so as to react about $2/3^{rd}$ of the tube walls, thereby leaving a sheath of un-reacted niobium at the tube periphery. As a result, when cooling down the ECN PIT wire to cryogenic temperatures in a small background magnetic field, a first transition occurs when the Nb_3Sn layers on the inner part of the tubes become superconducting, and a second transition follows when the un-reacted Nb sheaths on the outer part of the tubes, in turn, become superconducting. Furthermore, the amplitudes of the magnetizations measured in these two stages enable one to determine the magnetically-shielded volumes which are associated and, thereby, the outer diameters of the reacted Nb_3Sn layers and of the un-reacted Nb tubes. In our example, we get: 44 μm for the Nb_3Sn layers and 65 μm for the Nb tubes. These values are in good agreement with the physical values that can be estimated from a backscatter electron micrograph of a reacted tube. A summary of these measurements was presented at the Magnet Technology Conference (MT'19) in Genova (EDMS 688570). This paper also exhibits experimental evidences that part of the large flux jumps observed on this wire may originate in the un-reacted Nb phase.

Data from the nano- and micro-hardness measurements have been analyzed and cross-checked with available literature data, yielding a summary table of relevant material properties (Young's modulus, yield strength, maximum elongation and ultimate tensile strength) in the cold work state of the wire at the end of drawing (EDMS 567375V1). In parallel, tensile tests have been carried out at CERN (EDMS 592009) and at the BundesAnstalt für Materialforschung (BAM), in Berlin, on samples of the old ITER-type wire while complementary nano-hardness measurements on longitudinal cuts of this wire have been sub-contracted to EIAJ. Analyses of this second round of measurements led to an iteration on the table of material properties (EDMS 567375V2). This latter table presents provides a fairly consistent set of data that will be used in the FE model to study the behavior of two types of internal tin wires developed by Alstom/MSA: the old, ITER-type design and the new NED design (EDMS 575661).

2006 Summary

The main result so far has been the production by SMI of a new wire (B207) having the proper NED wire diameter (1.25 mm) and including 288 tubes of a similar design as for B179. The wire was delivered to CERN on 20 December 2005 and characterized at INFN-Mi and –Ge in January/February. The wire exhibits a high critical current (~1300 A at 4.2 K and 12 T, thus only 17% below the 1600 A target) but a somewhat disappointing critical current density (~2100 A/mm^2 at 4.2 K and 12 T; note that the wire copper-to-non-copper ratio is rather low: 0.955, while the specification is 1.25). This lower than anticipated critical current density is attributed to a problem in powder preparation. INFN-Mi also carried out stability current measurements, which did not show any flux-jump induced quench for field sweeps between 14 and 18 mT/s and currents up to the current supply limit of 1800 A. The magnetization measurements performed at INFN-Ge confirm that the wire exhibits few flux jumps and that the effective outer diameters of the Nb and Nb_3Sn tubes are conform to expectations: 58 μm for the Nb tubes and 46 μm for the Nb_3Sn tubes. Finally, rolling tests were carried out at CERN to study the wire sensitivity to deformation; critical current measurements performed at INFN-Mi on wires with a 0.35 mm diameter reduction yielded ~15-17% I_C degradation at 4.2 K and 12 T.
In the meantime, Alstom/MSA has pursued its investigation of the workability problems and has solved all the issues related to the manufacturing of sub-elements. It is now concentrating on the final stage and the first wire is expected at the end of June.

4.3.1 CD WP coordination

As already mentioned, the CD Work Package is articulated around three main poles: conductor development (encompassing Tasks 3.2, 3.3, 3.4 and 3.6), conductor characterization (encompassing Tasks 3.5 and 3.7), and mechanical studies (extension of scope with respect to CARE Annex I, initiated by INFN-Ge and partially supported by CERN).

The conductor development pole was launched by D. Leroy (CERN) and is presently coordinated by L. Oberli (CERN). A working Group on Conductor Characterization (WGCC), chaired by A. den Ouden (TEU) has been set up to coordinate the conductor characterization efforts, while S. Farinon (INFN-Ge) is the principal investigator on the mechanical model. The Pole Coordinators report to the NED Steering Committee and, ultimately, to the NED/JRA Coordinator.

4.3.2 Design of a 15 T Dipole Magnet

The following actions have been carried out

- ✓ September 2003–July 2004: preliminary design computations carried out by O. Vincent-Viry (CERN) under D. Leroy supervision (CERN)
- ✓ November 2003: report on 2D magnetic induction analytical calculation issued by O. Vincent-Viry (CERN; EDMS 431540)
- ✓ January 2004 SC meeting: first presentation of preliminary design computations by O. Vincent-Viry (CERN)
- ✓ 4 May 2004: meeting at CEA to review magnetic configurations and choice of 88-mm-aperture, cosθ layer as Reference Design V1 (EDMS 555825)
  participants: H. Félice, L. Quettier, J.M. Riflet, P. Védrine (CEA), A. Devred (CEA&CERN), D. Leroy and O. Vincent-Viry (CERN)
- ✓ 2 August 2004: seminar at CERN by O. Vincent-Viry (CERN) on preliminary magnet designs
- ✓ 16 February 2005: first version of preliminary design report issued by D. Leroy and O. Vincent Viry (CERN; EDMS 555826)
- ✓ 26 July 2005: final version of preliminary design report issued by D. Leroy and O. Vincent Viry (CERN; EDMS 555826V2); EU deliverable

Sub-Task completed

4.3.3 Specifications on Wire and Cable

The following actions have been carried out

- ✓ 11 May 2004: first draft specification issued by D. Leroy (CERN) and communicated to A. Devred (CEA&CERN)
- ✓ 14 May 2004: first draft reviewed by A. Devred (CEA&CERN)
- ✓ 18 May 2004: second draft specification issued by D. Leroy and communicated to A. Devred (CEA&CERN) and A. den Ouden (TEU)
- ✓ 1 June 2004: third draft specification issued by D. Leroy and communicated to NED SC

- ✓ 4 June 2004: Specification Committee Meeting at CERN
  participants: T. Boutboul, P. Bryant (Chairman), P. Lebrun, D. Leroy, L. Oberli, L. Rossi (CERN), H.H.J. ten Kate (CERN&TEU)]
- ✓ 18 June 2004: final specification and technical questionnaire issued by D. Leroy (CERN; EDMS 475443); EU deliverable

Sub-Task completed

4.3.4 Wire Development

The following actions have been carried out and/or are foreseen

- ✓ 12 December 2003: preparatory visit to Alstom/MSA, France
  participants: A. Devred (CEA&CERN), D. Leroy, T. Boutboul and L. Oberli (CERN)]
  EDMS: 739047
- ✓ 15 December 2003: preparatory visit to European Advanced Superconductors (EAS, Germany)
  participants: A. Devred (CEA&CERN), D. Leroy and L. Oberli (CERN) + SMI representative
- ✓ 27 January 2004: preparatory visit to ShapeMetal Innovation (SMI, The Netherlands)
  participants: A. Devred (CEA&CERN), D. Leroy, T. Boutboul, and A. Unervick (CERN) + EAS representatives
  EDMS: 739050
- ✓ 21 June 2004: call for tender issued to Alstom/MSA, EAS, Outokumpu Copper (OK Cu, Finland), Outokumpu SI (OKSI, Italy) and SMI
- ✓ 20 August 2004: meeting at CERN with SMI and EAS to prepare answer to call for tender
- ✓ 23 August 2004: meeting at CERN with OK to prepare answer to call for tender
- ✓ 24 August 2004: meeting at CERN with Alstom/MSA to prepare answer to call for tender
- ✓ 6 September 2004: tenders' opening at CERN; selection of Alstom/MSA and SMI
- ✓ 16 September 2004: visit of T. Boutboul, D. Leroy, L. Oberli (CERN) to Alstom/MSA
  EDMS: 739048
- ✓ 24 September 2004: sending of orders to CERN Finance Division
- ✓ 15 November 2004: contracts' signature by Alstom/MSA and SMI
- ✓ 15 December 2004: first progress reports issued by Alstom/MSA and SMI (restricted access)
- ✓ 17 May 2005: visit of T. Boutboul, D. Leroy, L. Oberli (CERN) to Alstom/MSA
- ✓ 28 June 2005: visit of T. Boutboul, D. Leroy, L. Oberli (CERN) to SMI
- ✓ 14 September 2005: visit of T. Boutboul, L. Oberli (CERN) to Alstom/MSA
- ✓ 21 October 2005: meeting at Archamps to discuss progress of Alstom/MSA
  participants: T. Boutboul, L. Oberli (CERN) and C. Verwaerde (Alstom/MSA)

- ✓ 29 November 2005: visit of T. Boutboul, D. Leroy, L. Oberli (CERN) to Alstom/MSA
- ✓ 10-11 January 2006: meeting at CERN to discuss progress of Alstom/MSA
  Participants: T. Boutboul, D. Leroy, L. Oberli (CERN), C. Verwaerde and L. Villars (Alstom/MSA)
- ✓ 14 March 2006: meeting at CERN to discuss progress of SMI
  Participants: T. Boutboul, D. Leroy, L. Oberli (CERN), J. Lindenhovius (SMI)
  EDMS : 739051
- ✓ 15 March 2006: meeting at CERN to discuss progress of Alstom/MSA
  Participants: T. Boutboul, D. Leroy, L. Oberli (CERN), G. Grumblatt and C. Verwaerde (Alstom/MSA)
- ✓ 10-11 April 2006: visit of T. Boutboul, D. Leroy, L. Oberli (CERN) to Alstom/MSA
  EDMS: 739049
- ⇒ November/December 2006: final wire production; EU deliverable

4.3.5 Wire Characterization

The following actions have been carried out and/or are foreseen

4.3.5.1 Definition of Measurement Procedures

- ✓ March 2004: setting up of Working Group on Conductor Characterization (WGCC), chaired by A. den Ouden (TEU)
  WGCC charges and composition: EDMS 548084
- ✓ 19 May 2004: first Working Group meeting at CERN
  participants: L. Quettier (CEA), V. Previtali (CERN), P. Fabbricatore and M. Greco (INFN-Ge), D. Pedrini, G. Volpini (INFN-Mi), A. den Ouden (TEU)
  Talks: EDMS 567255
- ✓ June 2004-October 2004: first round of test wires for cross-calibration purposes
- ✓ 28 October 2004: second Working Group meeting at CEA
  participants: L. Quettier (CEA), V. Previtali, T. Boutboul (CERN), M. Greco (INFN-Ge), D. Pedrini, G. Volpini (INFN-Mi), A. den Ouden (TEU)
- ✓ November 2004-January 2005: second round of test wires for cross-calibration purposes
- ✓ 22 February 2005: third Working Group meeting at INFN-Mi
  participants: L. Quettier (CEA), A. Devred (CEA&CERN), T. Boutboul and V. Previtali (CERN), M. Greco and P. Fabbricatore (INFN-Ge), D. Pedrini, G. Volpini (INFN-Mi)
  Talks and Minutes: EDMS 576267
- ✓ 3 May 2005: fourth Working Group Meeting at CERN
  participants: L. Quettier (CEA), T. Boutboul, D. Leroy, L. Oberli (CERN), M. Greco (INFN-GE), D. Pedrini, G. Volpini (INFN-Mi), A. den Ouden (TEU)
  Talks: EDMS 593632

- ✓ May-July 2005: third round of test wires for cross-calibration purposes (includes deformed wires by rolling)
- ✓ 22 November 2005: fifth Working Group Meeting at CERN
participants: L. Quettier (CEA), A. Devred (CEA&CERN),
T. Boutboul, L. Oberli V. Previtali (CERN), D. Pedrini (INFN-Mi),
A. den Ouden (TEU)
Talks: EDMS 682996
- ✓ 13 December 2005: final version of MT19 paper issued by A. den Ouden (TEU; EDMS 690009)
- ✓ December 2005-February 2006: final iteration on third round of cross calibration
- ⇒ 31 December 2006: final report on wire characterization; EU deliverable

4.3.5.2 Wire I_C Measurements

4.3.5.2.1 Wire I_C Measurements at CEA

- ✓ 11 October 2004: Report No 1 issued by L. Quettier (CEA; EDMS 722289)
- ✓ 14 February 2005: Report No 2 issued by L. Quettier (CEA; EDMS 722295)
- ✓ 25 April 2005: Report No 3 issued by L. Quettier (CEA; EDMS 722301)
- ✓ 27 July 2005: Report No 4 issued by L. Quettier (CEA; EDMS 722306)
- ✓ 4 October 2005: Report No 5 issued by L. Quettier (CEA; EDMS 722313)
- ✓ 17 November 2005: Report No 6 issued by L. Quettier (CEA; EDMS 722317)
- ✓ 9 February 2006: Report No 7 issued by L. Quettier (CEA; EDMS 722320)

4.3.5.2.2 Wire I_C Measurements at INFN-Mi

- ✓ 29 September 2004: Report No 1 issued by G. Volpini (INFN-Mi; EDMS 722401)
- ✓ 2 February 2005: Report No 2 issued by G. Volpini (INFN-Mi; EDMS 722410)
- ✓ April 2005: Report No 3 issued by G. Volpini (INFN-Mi; EDMS 722411)
- ✓ July 2005: Report No 4 issued by G. Volpini (INFN-Mi; EDMS 722414)
- ✓ January 2006: Report No 5 issued by G. Volpini (INFN-Mi; EDMS 722416)
- ✓ 2 February 2006: Report No 6 issued by G. Volpini (INFN-Mi; EDMS 722422

4.3.5.2.3 Wire I_C Measurements at TEU

- ✓ September 2004: Report No 1 issued by A. den Ouden (TEU; EDMS 722424)
- ✓ February 2005: Report No 2 issued by A. den Ouden (TEU; EDMS 722428)
- ✓ April 2005: Report No 3 issued by A. den Ouden (TEU; EDMS 722430)
- ✓ July 2005: Report No 4 issued by A. den Ouden (TEU; EDMS 722431)

4.3.5.3 Wire Magnetization Measurements at INFN-Ge

- ✓ 21 January 2004: preparatory meeting at CERN
  participants: A. Devred (CEA&CERN), D. Leroy (CERN) and
  P. Fabbricatore (INFN-Ge]
- ✓ 23 March 2004: first report on preliminary measurements issued by P. Fabbricatore and M. Greco (INFN-Ge)
- ✓ 23 March 2004–13 April 2004: review of preliminary measurements by A. Devred (CEA&CERN) and D. Leroy (CERN)
- ✓ June 2004-July 2005 2005: participation to cross-calibration program defined by WGCC
- ✓ 23 November 2005: highlight talk given by M. Greco (INFN-Mi) at the CARE general meeting at CERN
- ✓ 5 December 2005: final version of MT19 paper issued by M. Greco (INFN-Mi; EDMS 688570)
- ✓ 5 April 2006: meeting at CERN for discussing measurements on SMI PIT wire B207
  Participants: A. Devred (CEA&CERN), D. Leroy, L. Oberli (CERN)
  M. Greco (INFN-Ge)

4.3.6 Cable development and manufacturing

Not started

4.3.7 Cable Characterization

Not started

4.3.8 Mechanical Studies

These studies are an extension of scope with respect to CARE Annex I and are supported by additional resources provided by INFN-Ge and CERN.

The following actions have been carried out and/or are foreseen

- ✓ 28 January 2004: parameters of mechanical model for 19-subelement, internal tin wire issued by A. Devred (CEA&CERN; EDMS 548087)
- ✓ 30 January 2004: mesh proposal issued by S. Farinon (INFN-Ge)
- ✓ Early February 2004: review of mesh proposal by A. Devred (CEA&CERN), D. Leroy (CERN) and C. Verwaerde (Alstom/MSA)
- ✓ 25 March 2004: informal discussion of preliminary computation results
  participants: A. Devred (CEA), D. Leroy (CERN), S. Farinon (INFN-Ge), C. Verwaerde and P. Mocaer (Alstom/MSA)]
- ✓ 9 June 2004: meeting at CERN to review material properties and discuss computation results
  participants: A. Devred (CEA&CERN), T. Boutboul, P. Fessia,
  D. Leroy and S. Sgobba (CERN), S. Farinon and R. Musenich (INFN-Ge), P. Loverage (CCLRC)
- ✓ 7 July 2004: meeting at CERN to review material properties and discuss computation results
  participants: A. Devred (CEA&CERN), T. Boutboul, P. Fessia,
  L. Oberli M. Pojer and S. Sgobba (CERN), P. Fabbricatore and
  S. Farinon (INFN-Ge)

- ✓ September 2004: first contract issued to EIAJ to perform nano-indentation measurements on an un-reacted, internal-tin wire cross-section
- ✓ 14 October 2004: visit to EIAJ, Le Locle (CH)
participants: T. Boutboul, C. Scheuerlein, S. Sgobba (CERN)
trip report: EDMS 520095
- ✓ 29 October 2004: first report issued by EIAJ on nano-indentation measurements (EDMS 548100)
- ✓ 11 November 2004: meeting at CERN to review nano-indentation measurements performed at EIAJ
participants: A. Devred (CEA&CERN), T. Boutboul, P. Fessia, D. Leroy, L. Oberli, V. Previtali, D. Richter and S. Sgobba (CERN), P. Fabbricatore and S. Farinon (INFN-Ge)
- ✓ 11 November 2004: first report issued by C. Scheuerlein (CERN) on micro-hardness measurements at CERN (EDMS 548116)
- ✓ 22 November 2004: meeting at CERN to review micro-hardness measurements
participants: A. Devred (CEA&CERN), T. Boutboul, C. Scheuerlein, S. Sgobba and W. Scandale (CERN)
- ✓ 15 February 2005: second report issued by C. Scheuerlein (CERN) on micro-hardness measurements at CERN (EDMS 567297)
- ✓ 15 February 2005: meeting at CERN to update table of material properties to be used in FE model
participants: A. Devred (CEA&CERN), T. Boutboul, D. Leroy, C. Scheuerlein, S. Sgobba (CERN)
- ✓ 17 February 2005: report issued by T. Boutboul (CERN) on RRR measurements at CERN (EDMS 567365)
- ✓ 22 February 2005: table of material properties issued by S. Sgobba and C. Scheuerlein (CERN; EDMS 567375)
- ✓ 23 March 2005: note issued by T. Boutboul and L. Oberli (CERN) defining new parameters of internal tin wire (EDMS 575661)
- ✓ April 2005: second contract issued to EIAJ to perform nano-indentation measurements on a longitudinal cross-section of an un-reacted, internal-tin wire
- ✓ 9 May 2005: first version of report on UTS measurements at CERN issued by C. Scheuerlein (CERN; EDMS 567375)
- ✓ 6 June 2005: second version of report on UTS measurements at CERN issued by C. Scheuerlein (CERN; EDMS 567375V2)
- ✓ 6 October 2005: meeting at CERN to discuss results of tensile tests performed at BAM
participants: A. Devred (CEA&CERN), T.Boutboul, L. Oberli, C. Scheuerlein (CERN)
- ✓ 10 November 2005: visit of C. Scheuerlein to BAM (CERN; EDMS 681910)
- ✓ 11 November 2005: meeting at CERN to update Table of material properties (CERN; EDMS 567375V2)
participants: L. Oberli, C. Scheuerlein, S. Sgobba (CERN)
- ✓ 24 November 2005: meeting at CERN to discuss problems with FE modelling in the plastic range

participants: A. Desirelli and S. Sgobba (CERN), S. Farinon (INFN-Mi)

- ✓ 9 December 2005: report on "room temperature tensile properties of the powder-in-tube (PIT) Nb_3Sn strand SMI B201 for NED" issued by C. Scheuerlein (CERN; EDMS 688862)
- ✓ 6 April 2006: meeting at CERN for discussing FE mechanical model for PIT wires
  Participants: T. Boutboul, D. Leroy, L. Oberli (CERN) and S. Farinon (INFN-Ge)
- ⇒ 9 May 2006: meeting at CERN for discussing progress on FE mechanical model for PIT wires
  participants: T. Boutboul, D. Leroy, L. Oberli, C. Scheuerlein (CERN) and S. Farinon (INFN-Ge)
- ⇒ 21 May 2006: meeting at CERN for discussing progress on FE mechanical model for PIT wires

Table 4.3a: Status of the lowest Sub-Tasks level in the CD WP (as of 30 April 2006).

WBS #	Title	Original begin date (Annex 1)	Original end date (Annex 1)	Estimated Status	Revised end date
3.1	CD WP Coordination				
3.2	Design of a 15 T Dipole Magnet	1 January 2004	31 Dec. 2004	Completed	July 2005
3.3	Specifications on Wire and Cable	1 April 2004	30 June 2004	Completed	On time
3.4	Wire Development	1 July 2004	30 June 2006	Started	30 September 2006
3.5	Wire Characterization				
3.5.1	Definition of Measuring Procedures	1 January 2004	30 June 2005	90%	30 April 2006
3.5.2	Ic measurements at CEA	1 July 2005	30 June 2006	Started	31 December 2006
3.5.3	Ic measurements at INFN-Mi	1 July 2005	30 June 2006	Started	31 December 2006
3.5.4	Ic measurements at TEU	1 July 2005	30 June 2006	Started	31 December 2006
3.5.5	Wire Magnetization Measurements	1 July 2005	30 June 2006	Started	31 December 2006
3.6	Cable Development	1 July 2005	31 Dec. 2006	Not started	-
3.7	Cable Characterization	1 October 2005	31 Dec. 2006	Not started	-
3.8	Mechanical Studies[a)]	1 January 2004	31 Dec. 2005	50%	30 September 2006

[a)] Extension of scope with respect to CARE Annex I.

Table 4.3b: Status with respect to the milestones and deliverables due in the CD WP (as of 30 April 2006).

WBS #	Title	Responsible Lab(s)	Due date in Annex 1	Status	Revised delivery date
3.2	Design Report (deliverable)	CERN	31 December 2004	Completed	July 2005
3.3	Final Report on Wire and Cable Specifications (deliverable)	CERN	30 June 2004	Completed	On time
3.4	Progress Report on Wire Development (milestone)	CERN	30 June 2005[a)]	Completed Completed	15 December 2004 31 December 2005
3.4	Production of Final Wire (deliverable)	CERN	30 June 2006	Not started	15 December 2006
3.5	Intermediate Results on Wire Characterization (milestone)	CEA, INFN-Ge, INFN-Mi, TEU	31 December 2005	Started	30 June 2006
3.5	Final Report on Wire Characterization (deliverable)	CEA, INFN-Ge, INFN-Mi, TEU	30 June 2006	Not started	31 December 2006
3.6	Production of Final Cable (deliverable)	CERN	31 December 2006	Not started	-
3.7	Final Report on Cable Performances (deliverable)	TEU	31 December 2006	Not started	-

[a)] The CARE Annex I milestone entitled “First Results on Wire Development” that was due on 30 June 2005 has been split into three “Status Reports” due on 15 December 2004 and 31 December 2005.

4.4 Work Package 4: Insulation Development & Implementation (IDI)

Work Package 4 includes two main Tasks:

- conventional insulation development
  (carried out by CCLRC/RAL, Task Leader: S. Canfer)
- innovative insulation development
  (carried out by CEA, Taks Leader: F. Rondeaux)

2004 Summary

CCLRC and CEA have written an engineering specification for the NED conductor insulation (EDMS 548037) and a coordinated Test Programme for the conventional and innovative insulations (EDMS 548038).

CCLRC has started investigations on glass fiber sizings and epoxy resin fillers and is developing an experimental set up to perform fracture tests based on a double-cantilever beam (DCB).

The start of the work on Innovative Insulation at CEA (Task 4.4) has been delayed, pending the hiring of a technician to support the activity of the chemistry laboratory.

2005 Summary

Screening testing of candidate materials for Conventional Insulation has progressed well. CCLRC has developed a standardised laminate production system and relies on three tests for screening: (1) inter-laminar fracture test, (2) short-beam shear test and (3) electrical breakdown test. The standard laminates leave sufficient material for radiation testing.

To gain experience and validate the inter-laminar fracture tests, three know systems of epoxy resins have been investigated: (1) a brittle system made up of DGEBA resin with an acid anhydride hardener (HY918, Ciba), (2) a tough system, made up of DGEBA resin with an aliphatic amine hardener (Jeffamine D-400), and (3) an intermediary system, made up of DGEBF resin, a PPGDGE flexibiliser and an aromatic amine hardener (HY5200, Ciba). All samples were prepared using as received E-glass tapes with commercial sizing, and the tests were performed at room temperature and at 77 K. As expected, the brittle system yields the lowest work of fracture (~0.45 kJ/m^2 at room temperature), while the toughest system yields the highest one (~1 kJ/m^2 at room temperature), and the intermediary system is in between (~0.8 kJ/m^2 at room temperature). The results are in the same order, but 20 to 40% higher at 77 K.

Furthermore, CCLRC has investigated the issue of fibre glass sizing. The sizing that coats the filaments of commercial fibre tapes is a mixture of organic materials that is not intended for high temperature use, and, if left in place, can result in undesirable carbon residues at the end of the Nb_3Sn reaction cycle. In practice, the sizing is removed from the tapes (by carbonization in air at temperatures in the 350-450 ºC range) prior to conductor wrapping and winding. However, removing the sizing renders the tape fragile and easy to tear off by friction, which complicates the manufacturing process. In addition, sizing removal has proved to have a bearing on the mechanical and electrical performances of the final insulation system. CCLRC has identified an improved sizing material, which is a commercial polyimide produced by Hydrosize, NC, USA that may sustain the Nb_3Sn reaction cycle without deleterious degradation. This sizing has been applied to glass and quartz fibre fabric by JPS Glass, SC, USA.

To assess the suitability of the polyimide sizing, CCLRC has undertaken a comparative test on standard laminates made up of conventional S-glass tapes (as received, de-sized and heat treated for 60 hours at 660 ºC in a vacuum after de-sizing) and of polyimide-sized, S-glass and quartz fabrics provided by JPS (as received and heat-treated for 60 hours at 660 ºC in a vacuum without de-sizing). The laminates were vacuum-impregnated with a system made up of DGBEF resin (DER354P, Dow) and a DETDA hardener (HY5200, Vantico). (This system was chosen because it is both relatively radiation stable and has a low viscosity, and, thereby, seems the best suited to NED application). The work of fracture measured on the conventional, as-received, S-glass sample is 0.49 kJ/m^2 at room temperature, which puts the resin system into the brittle category (not unexpected given the nature of the hardener that was chosen). No meaningful work of fracture could be measured on the conventional, de-sized, heat-treated, S-glass sample. Indeed, the sample failed through the glass layer and not in an inter-laminar fashion, thereby indicating that the glass was adversely affected by heat treatment. The results on the polyimide-sized, S-glass samples are very promising: the work of fracture on the sample made up of as-received fabric is 0.7 kJ/m^2 at room temperature and stays at 0.67 kJ/m^2 on the sample made up of heat-treated fabric. The short-beam shear strengths measured at 77 K are above ~90 MPa for all samples, save for the conventional, de-sized, heat-treated, S-glass sample where it falls to 69 MPa. Finally, electrical breakdown tests were carried out on conventional, heat-treated, de-sized and not de-sized S-glass samples and on heat-treated, polyimide-sized S-glass samples. The voltage measured on the conventional, de-sized sample and on the polyimide-sized sample are both in excess of 30 kV/mm, while the one measured on the sample made up of conventional S glass, heat-treated without de-sizing, is degraded to 2.5 kV/mm. Preliminary results on this sub-task were reported in a paper presented at ICMC2005 in Keystone, CO (EDM 685456)

The work on the Innovative Insulation is still on hold pending the hiring of a technician in the chemistry lab at CEA, which has been further delayed until the end of 2005. To compensate this delay, it has been decided to re-allocate part of the EU funding to hire a postdoc at CEA.

2006 Summary

Work is continuing at CCLRC/RAL to better characterise the thermal limits of the polyimide sizing material. Thermo-Gravimetric Analysis is being used in argon and vacuum environments to mimic the processing of a real magnet coil. The minimal weight loss of the sizing is proving difficult to measure, since the sizing is present at less than 1% by weight on glass fibre. In addition it is difficult to prepare a sample with sufficiently high mass to produce results that overcome experimental variation and noise.

The work on innovative insulation was restarted at CEA on 3 April 2006, thanks to the arrival of a NED-funded additional staff.

4.4.1 IDI WP Coordination

The IDI Work Package is coordinated by E. Baynham (CCLRC). The conventional Insulation Task (4.3) is headed by S. Canfer (CCLRC) while the Innovative Insulation Task (4.4) is headed by F. Rondeaux (CEA). The Work package and Task Leaders report to the NED Steering Committee and, ultimately, to the NED/JRA Coordinator.

4.4.2 Specifications' Drafting

The following actions have been carried out

- ✓ 6 May 2004: draft specifications issued by S. Canfer (CCLRC)
- ✓ 11 May 2004: conference call on insulation specifications
- ✓ participants: S. Canfer and J. Greenhalgh (CCLRC), F. Rondeaux (CEA), A. Devred (CEA&CERN), A. den Ouden (TEU)
- ✓ 11 May 2004: Version 2 of specifications issued by S. Canfer (CCLRC; EDMS 548037V1)
- ✓ 25 May 2004: Version 2.2 of specifications issued by S. Canfer (CCLRC; EDMS 548037V2)
- ✓ 1 June 2004: Version 2.3 of specifications issued by S. Canfer (CCLRC; EDMS 548037V3)
- ✓ 23 June 2004: Version 2.3b of specifications issued by S. Canfer (CCLRC; EDMS 548037V4)
- ✓ 16 July 2004: final specifications (EDMS 548037V5); EU milestone

Sub-Task completed

4.4.3 Conventional Insulation

The following actions have been carried out and/or are foreseen

- ✓ 27 July 2004: first draft of conventional insulation Test Programme (EDMS 548038V1)
- ✓ 12 August 2004: second draft of conventional insulation Test Programme
- ✓ 27 October 2004: final insulation Test Programme (including Test Programme for innovative insulation; EDMS 548038V2); EU milestone
- ✓ 30 September 2004: completion of Literature Survey (Sub-Task 4.3.1)
- ✓ 30 November 2004: completion of Tooling Preparation (Sub-Task 4.3.2)
- ✓ 31 December 2004): completion of Component Supply (Sub-Task 4.3.3)
- ⇒ 1 January 2005 – 31 May 2006: Iterative Tests (Sub-Task 4.3.4)
- ⇒ 1 October 2005 – 30 June 2006: Data Analysis (Sub-Task 4.3.5)
- ⇒ 1 July 2005 – 30 June 2006: Irradiation Tests (extension of scope with respect to CARE Annex I); first neutron irradiation to be completed in May 2006
- ⇒ 22 February 2006: visit of S. Canfer and G. Ellwood (CCLRC) to CERN polymer laboratory (with S. Ilie)
- ⇒ 30 June 2006: final report on conventional insulation; EU deliverable

4.4.4 Innovative Insulation

The following actions have been carried out and/or are foreseen

- ✓ 6 May 2004: preparatory meeting at CEA

- ✓ participants: J.M. Rifflet, F. Rondeaux and P. Védrine (CEA), A. Devred (CEA&CERN); conclusions of this meeting are reported above
- ✓ 30 August 2004: first draft of innovative insulation Test Programme
- ✓ September 2004: final innovative insulation Test Programme (added to EU milestone on conventional insulation Test Programme)
- ✓ 3 April 2006: hiring of Patrick Fourcade by CEA (additional staff for 1 year)
- ⇒ 3 April 2006 – 31 December 2006: Tape Weaving Trial (Sub-Task 4.4.1)
- ⇒ 3 April 2006 – 31 March 2007: Characterization Tests (Sub-Task 4.4.2; scope has been modified with respect to CARE Annex I)
- ⇒ 31 March 2007: final report on innovative insulation; EU deliverable

Table 4.4a: Status of the lowest Sub-Tasks level in the IDI WP (as of 30 April 2006).

WBS #	Title	Original begin date (Annex 1)	Original end date (Annex 1)	Estimated Status	Revised end date
4.1	IDI WP Coordination				
4.2	Specifications' Drafting	1 April 2004	30 June 2004	Completed	22 July 2004
4.3	Conventional Insulation				
4.3.1	Literature Survey	1 July 2004	30 Sept. 2004	Completed	On time
4.3.2	Tooling Preparation	1 October 2004	30 October 2004	Completed	31 Dec. 2005
4.3.3	Component Supply	1 October 2004	31 Dec. 2004	Completed	On time
4.3.4	Iterative Tests	1 January 2005	30 Sept. 2005	90%	31 May 2006
4.3.5	Data Analysis	1 October 2005	31 Dec. 2005	80%	30 June 2006
4.3.6	Irradiation tests[a)]	1 July 2005	30 June 2006	In progress	30 June 2006
4.4	Innovative Insulation				
4.4.1	Tape Weaving Trial	1 July 2004	31 Dec. 2004	Just started	31 December 2006
4.4.2	Characterization Tests[b)]	1 July 2004	30 June 2005	Just started	31 March 2007

[a)] Extension of scope with respect to CARE Annex I.
[b)] Modification of scope with respect to CARE Annex I.

Table 4.4b: Status with respect to the milestones and deliverables due in the IDI WP (as of 30 April 2006).

WBS #	Title	Responsible Lab(s)	Due date in Annex 1	Status	Revised delivery date
4.2	Report on Specifications for Conductor Insulation (milestone)	CCLRC	30 June 2004	Completed	22 July 2004
4.3&4.4	Report on Definition of the Test Programme (milestone)[a)]	CCLRC&CEA	31 July 2004	Completed	27 October 2004
4.3	Report on Conventional Insulation (deliverable)	CCLRC	31 December 2005	In progress	30 June 2006
4.4	Report on Innovative Insulation (deliverable)	CEA	30 June 2005	Not started	31 March 2007

[a)] Scope of report has been extended to include test programme on innovative insulation (Task 4.4).

4.5 Working Group on Magnet Design and Optimization (WGMDO)

2004 Summary

CCLRC, CEA, CERN and CIEMAT have decided to join forces in order to create an informal Working Group on Magnet Design and Optimization (WGMDO), whose charges and composition are defined in EDMS 547882.

The Working Group is made up of

- H. Félice (CEA)
- P. Fessia (CERN)
- P. Loveridge (CCLRC)
- J. Rochford (CCLRC)
- S. Sanz (CIEMAT)
- F. Toral-Fernandez (CIEMAT), Technical Secretary
- P. Védrine (CEA), Chairman

This Working Group is an extension of scope with respect to CARE Annex 1. It is supported by CCLRC (whose contribution foreseen to Task 3.2 has been shifted to this end) and by additional resources from CEA, CERN and CIEMAT.

The Working Group has agreed on a common set of high-field-dipole-magnet design parameters (EDMS 547884) and on a common set of material properties, such as iron yoke *B*-*H* curve (EDMS 555825) and Young's modulii and integrated thermal expansion coefficients (EDMS 683000V5). Then, it has selected a number of magnetic configurations to be studied and compared, which include:

- the conventional, cosθ, layer design,
- Pérot's cosθ, slot design,
- a so-called *ellipse-type* design proposed by CEA,
- a so called *motor-type* design proposed by CIEMAT,
- the twin-aperture, common-coil design, first proposed by G. Danby at Brookhaven National Laboratory (BNL) in 1983 and subsequently resuscitated by R. Gupta in 1996,
- the double-helix or helical dipole design first investigated in the 1970's.

The comparison will be carried out in three steps: (1) comparison of 2-D electromagnetic designs, (2) comparison of 2-D mechanical designs and (3) comparison of 3-D designs. Each partner has chosen one or two configurations and has started to work on 2-D electromagnetic and mechanical designs.

2005 Summary

CCLRC/RAL has chosen to investigate the Reference Design V1, cosθ, layer design and to assess the feasibility of a double-helix magnetic configuration. The cosθ optimization was carried out using software supplied by the commercial company Vector Fields, which has close links with the RAL magnet group. At first, the software was used to construct a 2D parameterized FE model, which includes the option of modeling the nonlinear effects of iron and a non-uniform current density in the conductor winding (as generated by the slightly-keystoned, NED Rutherford-type cable). A number of test cases were run to check the optimizer provided by Vector Fields and to look at the effects of changing the objective functions. The output from the full model has now been compared with ROXIE and it gives the same results for the same geometry and field. Investigations are being carried out to determine whether the optimizer routines from both packages yield the same solutions, given the same starting point. The work on the helical dipole configuration has just begun and a basic model capable of being used with the VF optimizer has been built and is ready to run.

In parallel, CCLRC/RAL has started the development of a 2D mechanical model of NED Reference Design V1 based on ANSYS®. The model is in two steps. The first step includes the coil assembly, the ground plane insulation, pairs of austenitic steel collars and keys. It is used to simulate the collaring process during which the collars are implemented around the insulated coil assembly and are clamped by means of the keys to pre-compress the coil azimuthally. The second step includes the aforementioned collared-coil assembly completed by a two-piece, horizontally-split, iron yoke and a welded outer shell that holds the coldmass together. The two yoke halves are assembled around the collared-coil assembly in such way that there remains a gap at their midplane. The room-temperature coil pre-compression after collaring and the yoke midplane gap after shell welding must be optimized to ensure that, when the magnet is cold and energized, the coil remains under compression and the yoke midplane gap is closed, thereby providing a very stiff support against the Lorentz force. The first step of the model is now fully operational, while the details of the second step are being worked out.

CEA has been working on an original design referred to as *ellipse-type*, and has carried out 2D electromagnetic analyses of 88-mm-, 130-mm- and 160-mm-aperture models using ROXIE. It has been shown that, in each case, accelerator-field quality can be reached by optimizing the conductor distribution and that the peak-to-central-field ratio is very advantageous. Nevertheless, the Lorentz forces involved are huge a lot of attention has to be paid to the mechanical design. CEA is presently developing a mechanical model of the 130-mm-aperture design based on CASTEM.

In parallel, and at the margin of the WGMDO efforts, CEA has been subcontracted by EFDA to study a 130-mm-aperture, 12.5-central-field, dipole magnet relying on a conventional $\cos\theta$, layer design. The preliminary mechanical analysis carried out as part of this study concludes that the Lorentz stresses originating in the coils are excessive and that there is no easy way to control and limit them. This may indicate that such a field level in such an aperture is out of reach for the conventional $\cos\theta$, layer design and that one needs to rely on a different magnetic configuration.

CERN has pursued the 2D electromagnetic optimization of Reference Design V1 with ROXIE. The optimization was carried out with respect to

- conductor geometry (to minimize all multipole coefficients and improve radial positioning of conductor blocks in 2D cross-section),
- shape of iron yoke inner boundary (to minimize saturation effects),
- size and implementation of ferromagnetic shims (to compensate superconductor magnetization effects).

The re-optimization is now completed and has led to the definition of a new reference design, referred to as Reference Design V2 (EDMS 692145), with a good field quality (all multipole coefficients are below 1 unit at a reference radius of 29 mm, save for the normal 18-pole, b_9, which is equal to 1.7 unit and the normal 22-pole, b_{11}, which is equal to 2.7 unit), efficient peak-to-central field ratio (~1.03 to 1), 15.0 T conductor peak field for a quench current of 29.4 kA and a more radial conductor distribution.

Regarding iron saturation, computations were carried out for the conductor distribution of Reference Design V2 and two different yoke configurations: one with a circular inner boundary (with an inner radius of 125.4 mm) and one with an optimized, elliptical inner boundary (with a vertical, half major axis of 136.6 mm and an horizontal, half minor axis of 125.4 mm). Relying on an elliptical inner boundary enables one to reduce the b_3 peak-to-peak variations by a factor ~3.
Regarding superconductor magnetization, computations were carried out either computed when taking into account the full effect (no corrective shims) and or when introducing two ferromagnetic shims at suitable locations inside the coils: one 1.5-mm-thick shim attached right below the upper wedge of the outer layer and one 0.7-mm-thick shim attached right below the middle wedge of the inner layer. The effects of persistent magnetization currents were estimated using a ROXIE feature which combines a vector hysteresis model for hard superconductors with the BEM-FEM method and which relies on a given $J_C(B)$ fit function for the superconducting filaments. The $J_C(B)$ function used in the simulation was extracted from magnetization measurements performed by Twente University on an existing 0.9-mm-diameter, 504-filament PIT wire, produced by SMI in 2000, appropriately rescaled to NED specifications (in particular, with respect to the non-copper critical current density of 3000 A/mm^2 at 4.2 K and 12 T and to the effective filament outer diameter of 50 μm; EDMS 638344). The introduction of the two ferromagnetic shims enables one to reduce the b_3 variations during the up-ramp (lower part of the hysteresis curves) by a factor in excess of 3.
These encouraging results show that the selected correction schemes can be quite effective (at least on the normal sextupole coefficient, b_3), and that we do have some means of compensating the effects of both iron saturation and superconductor magnetization.

CIEMAT has worked on the 2D electromagnetic analysis of the 88-mm- and 130-mm-aperture motor-type design and of the 88-mm-aperture common-coil design using ROXIE. Starting from the set of design parameters agreed upon by the Working Group, the field quality has been optimized in the cross-section while keeping an eye on the feasibility of the mechanical design and on the Lorentz forces to be handled. For both configurations, the number of design variables is enough to get an optimum field quality, as well as a good peak-to-central field ratio. However, the motor-type design appears to yield a high fringe field while calling for a large superconductor volume.

2006 Summary

CCLRC/RAL has improved the mechanical analysis of the cross section of the NED Reference Design V1. The collar assembly had already been modelled in the first stage of the calculation. The second step, that consists of the iron yoke and the stainless steel outer shell assembly, has been successfully included. Frictionless contact has been considered in the interfaces between the yoke and the collars, the yoke and the outer shell, and both halves of the yoke. A one millimeter nominal radial interference fit exists between the shell and the yoke at room temperature. The induced stress in the shell is ~370 MPa. The third step of the mechanical analysis is the modelling of the cooldown from room temperature to working conditions (4.2 K). At low temperature, the yoke midplane gap is completely closed. Finally, the fourth step takes into account the electromagnetic forces due to the magnet powering. A benchmark exercise has been also realised between three different codes: Ansys, Roxie and Vectorfields, showing a very good agreement, within 1% accuracy. The horizontal component of the Lorentz forces is quite large. As a consequence, a loss of contact occurs at the collar pole for the inner coil layer, while the azimuthal stresses at the coil mid-plane are too high (the affordable limit is 150 MPa). Therefore, there is a number of parameters still to optimize in order to minimize that peak azimuthal stress:

- Preload applied to coil prior to powering.
- Shape of iron at yoke/collar interface.
- Shape of iron mid-plane gap.
- Young's moduli for wedges and spacers in the coils.

A cable submodel is under development. This approach makes possible a local study of the peak stress on the superconducting strands and on the cable insulation. The submodel boundary conditions are stated from the global model results. Isotropic material properties are considered up to now, but orthotropic ones will be included to get more accurate results.

CEA has been working on a mechanical model of the 130-mm-aperture elliptic design based on CASTEM. An internal support has been introduced to prevent the coils from bending due to the vertical component of the Lorentz forces. The drawback is the decrease of the free aperture. The iron yoke and the collars are vertically split to allow the prestress of the coils by means of an outer stainless steel shell. Frictionless contact surfaces are modelled between the collars and the yoke, and also between the yoke and the shell. The assembly, cooldown and Lorentz forces are considered for a correct modelling. The preliminary results show that the peak stresses on the coils can be kept below 150 MPa. Future work will include orthotropic material properties for the wedges and the coils, and will optimise the mechanical structure dimensions.

CERN has performed a parametric analysis of forces and stresses in sector winding superconducting quadrupole coils, which could be easily extended also to dipoles. This study aims at the minimization of the peak stress on the coils for a given gradient, as a function of the aperture and the coil thickness. The quadrupole modelling is simplified: an infinitely stiff radial support is assumed, while neither iron yoke nor pre-stress are included. The magnetic field in the aperture, the stored magnetic energy, the Lorentz forces and the stress distribution in the coils (due only to the electromagnetic forces, the cooldown is not modelled) are computed with both analytical and numerical methods. Two different approaches are used for analytical calculations: a cos-θ current distribution or a sector winding with uniform current density. The numerical analysis is done by means of the finite element method (Ansys). Two superconducting materials are considered, NbTi and Nb_3Sn, and their critical current properties are parametrized for the optimization.
Analytical methods provide a good estimate of the field in the aperture, but not so good at the coils. However, analytical approaches yield a good estimate of the forces and stresses if an adequate value of the peak field is used. Anisotropic coil material properties does not affect significantly the stress distribution. Therefore, despite analytical models can only include isotropic materials, their results are quite accurate. The peak stress along the mid-plane coil increases almost linearly with the aperture for a given coil thickness. The peak stress along the mid-plane shows a very non-linear behaviour for a set aperture while varying the coil width. For a given aperture, there is coil width (gradient) for which this stress is minimized.The stress on the outer edge provides a good hint to evaluate the behaviour of the peak stress.

CIEMAT has studied a way to decrease the high stray field of the former motor-type design. An additional coil block is included close to the outer coil blocks with opossite polarity current. Two main advantages arise: the fringe field decreases sharply with the radial distance to the magnet, as the magnetic moment of the overall outer blocks is very low; and the number of ampere-turns is about one half than in the previous model, because the field in the aperture is now mainly created by the inner coil blocks. However, one important problem is still to solve: the mechanical assembly is getting complex, and further mechanical analysis

should be done on the coil end stress distribution. Besides, the fringe field is still high close to the yoke outer radius, and it is not possible to be decreased with an iron screen, which even enhances locally the field. This coil configuration has been optimized for the three given apertures: 88, 130 and 160 mm. Self-inductance is about twice higher while the superconductor efficiency and the ratio of bore to peak field are lower than in the cos-θ reference design, but the Lorentz forces are lower, and the average compression on the midplane is around 100MPa. Further quench protection studies are mandatory. One can also conclude that the cosθ slotted design becomes a very interesting choice, as the cross-section has none drawbacks, although the coil end design is still a challenging engineering problem.
The common coil design study has been completed for the three apertures. The optimization has not been done automatically, because the necessary design variables were not available in Roxie, but they will be in the near future. Genetic algorithms implemented in Roxie could enhance the magnet performance. Therefore, the field quality is still not completely optimized. For the time being, the main conclusions are that the most effective turns are being replaced by spacers to improve the high field quality. However, the distance between both apertures can be increased, as the overall present size of this magnet is half of the other designs size. In such a way, the crosstalk will also be decreased, and likely the ratio of the bore to peak field, because the field lines density between the symmetric coil blocks will decrease. Another possible method to improve the field quality is the addition of some auxiliary coils, but the magnet assembly becomes more complex.

Further information about the activities developed in 2006 is available in EDMS system under reference number 719322..

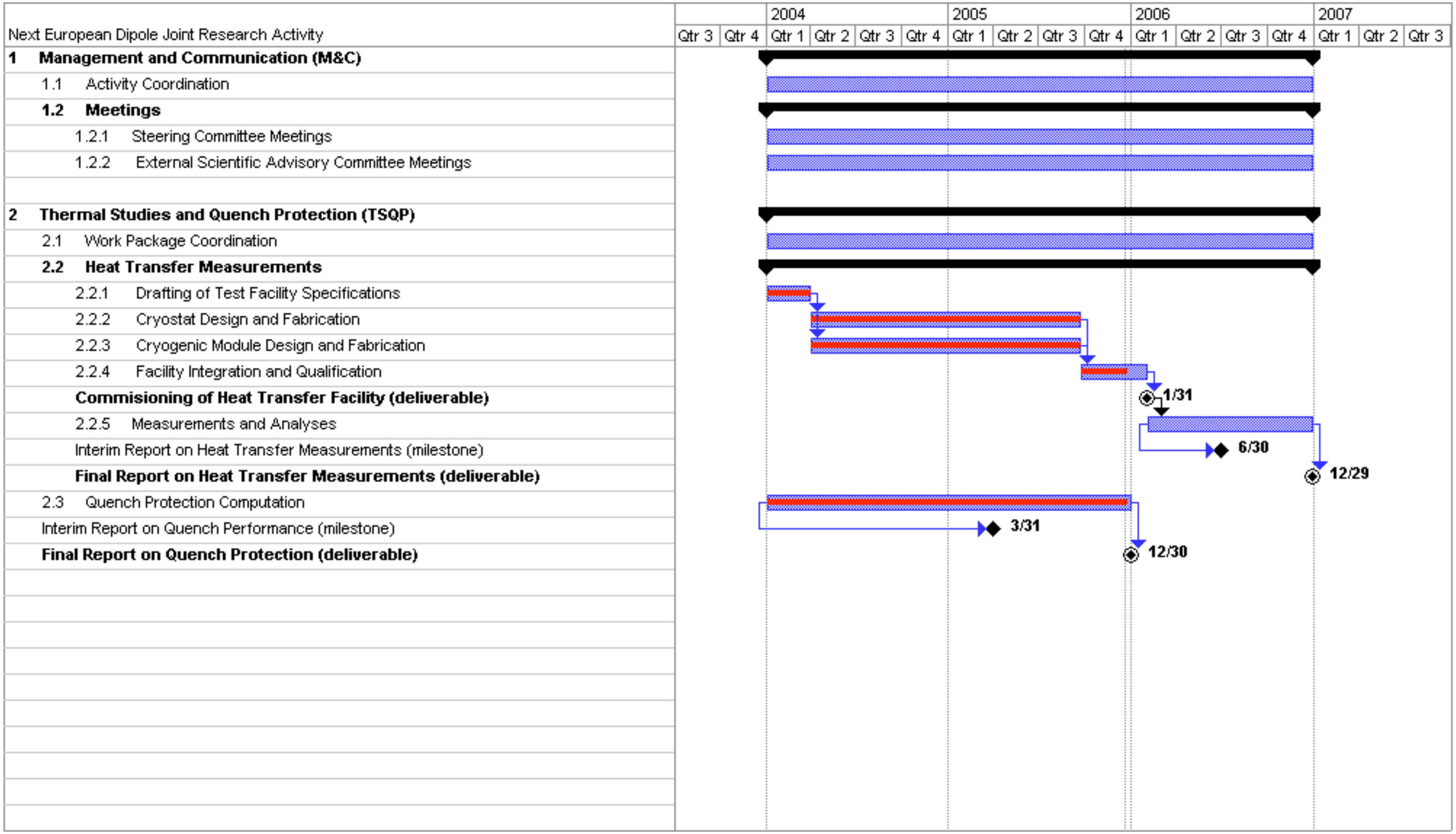
The following actions have been carried and/or are foreseen

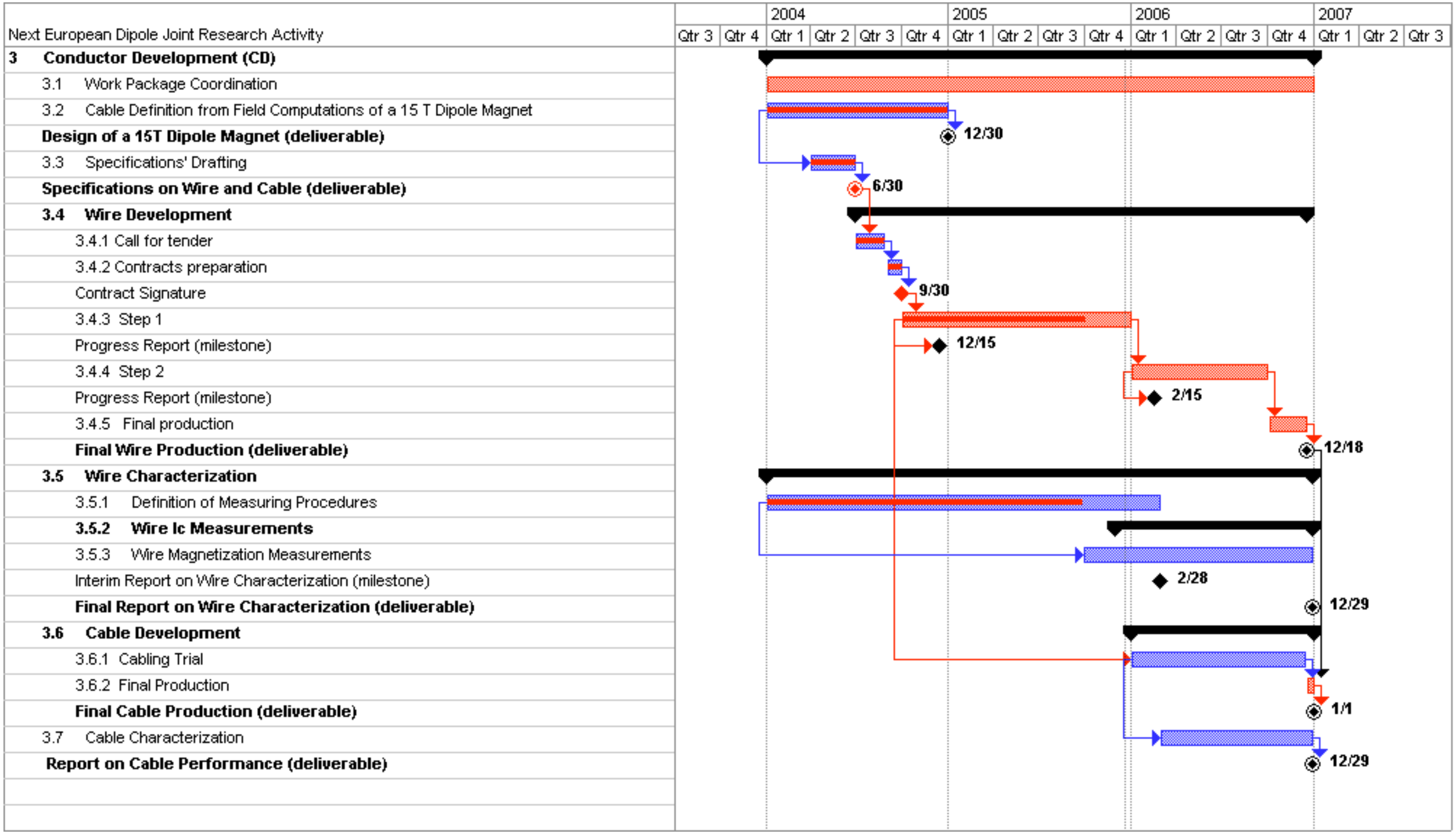
- ✓ 19 May 2004: brainstorming session at CEA/Saclay
  participants: H. Felice, L. Quettier and P. Védrine (CEA), A. Devred, (CEA&CERN), P. Fessia (CERN), S. Sanz and F. Toral (CIEMAT), P. Loveridge and J. Rochford (CCLRC)
  preparatory document: EDMS 547883
  minutes: EDMS 547884
- ✓ 23 November 2004: meeting at CERN to discuss CCLRC computations on NED baseline (88-mm-aperture, cosθ, layer) design
  participants: D.E. Baynham and P. Loveridge (CCLRC), A. Devred, (CEA&CERN), D. Leroy (CERN)
- ✓ 17 December 2004: WGMDO meeting at CIEMAT to review 2-D magnetic designs
  participants: P. Loveridge, J. Rochford (CCLRC), H. Felice, P. Védrine (CEA), A. Devred (CEA&CERN), S. Sanz, F. Toral (CIEMAT)
  talks and minutes: EDMS 547885
- ✓ 27 January 2005: visit of P. Loveridge (CCLRC) to CEA to discuss FE modelling
  participants: P. Loveridge (CCLRC), M. Ségréti and P. Védrine (CEA), A. Devred (CEA&CERN)
- ✓ 13 April 2005: meeting at CERN to discuss CCLRC progress on ANSYS model of NED Reference Design V1
  participants: E. Baynham, P. Loveridge (CCLRC), A. Devred (CEA&CERN), P. Fessia and M. Pojer (CERN)
- ✓ 13 April 2005: WGMDO meeting at CERN

participants: E. Baynham, P. Loveridge, J. Rochford (CCLRC), H. Félice (CEA), A. Devred (CEA&CERN), P. Fessia, N. Schwerg (CERN), S. Sanz and F. Toral (CIEMAT)
talks and minutes: EDMS 581911

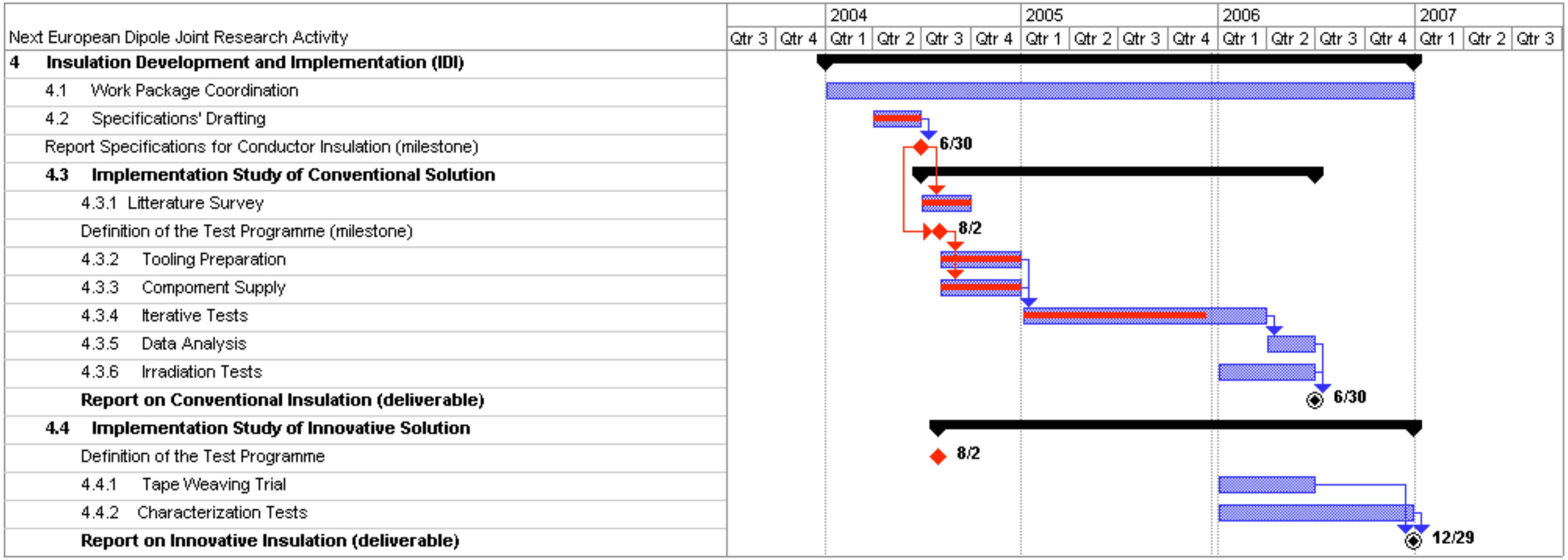
- ✓ 14 June 2005: WGMDO meeting at CCLRC to review progress on 2-D magnetic and mechanical designs
  participants: E. Baynham, S. Canfer, C. Densham, J. Greenhalgh, P. Loveridge, J. Rochford, (CCLRC), H. Félice (CEA), A. Devred (CEA&CERN), N. Schwerg (CERN), S. Sanz and F. Toral (CIEMAT)
  talks and minutes: EDMS 600861
- ✓ 23 June 2005: meeting at CERN to discuss CCLRC progress on ANSYS model of NED Reference Design V1
  participants: E. Baynham (CCLRC/RAL), A. Devred (CEA&CERN) and D. Leroy (CERN)
- ✓ 1 September 2005: start date of Federico Regis at CERN, as unpaid associate supported by a Associazione Sviluppo Tecnologico e Scientifico Piemonte (ASP) grant, to work on NED mechanical design under the supervision of P. Fessia (CERN)
- ✓ 27 September 2005: CERN/AT/MAS seminar of N. Schwerg (CERN) on "Optimization of the coil cross section for NED"
- ✓ 6 October 2005: meeting at CERN to discuss CCLRC progress on ANSYS model of NED Reference Design V1
  Participants: E. Baynham, P.Loveridge (CCLRC/RAL), A. Devred (CEA&CERN), D. Leroy (CERN)
- ✓ 21 November 2005: Version 4 of Table of material properties issued by P. Loveridge (CCLRC/RAL; EDMS 683000V4)
- ✓ 22 November 2005: WGMDO meeting at CERN to review progress on 2-D magnetic and mechanical designs
  participants: P. Loveridge, (CCLRC), H. Félice (CEA), A. Devred (CEA&CERN), B. Auchmann, P. Fessia. D. Leroy, M. Pojer, F. Regis S. Russenschuck (CERN), S. Sanz and F. Toral (CIEMAT), A. den Ouden (TEU)
  agenda and talks: EDMS 682994
- ✓ 16 December 2005: Version 5 of Table of material properties issued by P. Loveridge (CCLRC/RAL; EDMS 683000V5)
- ✓ 15 March 2006: meeting at CERN to discuss CCLRC progress on ANSYS model of NED Reference Design V1
  Participants: E. Baynham, P.Loveridge (CCLRC/RAL), A. Devred (CEA&CERN), D. Leroy (CERN)
- ✓ 4 April 2006: meeting at CERN to discuss CCLRC progress on ANSYS model of NED Reference Design V1
  Participants: E. Baynham, P.Loveridge (CCLRC/RAL), A. Devred (CEA&CERN), D. Leroy (CERN)
- ✓ 7 April 2006: WGMDO meeting at CERN to review progress on 2-D magnetic and mechanical designs
  participants: P. Loveridge, (CCLRC), H. Félice (CEA), A. Devred (CEA&CERN), P. Fessia, F. Regis, C. Vollinger and N. Schwerg (CERN), F. Toral (CIEMAT)
  agenda and talks: EDMS 719322
- ⇒ next WGMDO meeting: 11 July 2006 at CERN

5 APPENDIX 1: IMPLEMENTATION PLAN (GANTT CHART) FOR THE NED/JRA AS DESCRIBED IN THE TECHNICAL ANNEX OF CARE CONTRACT (EDMS 548031); LAST UPDATE: 15 DECEMBER 2006





NB: the CARE Annex I milestone entitled “First Results on Wire Development” that was due on 30 June 2005 has been split into two “Status Reports” due on 15 December 2004 and 15 December 2005.



NB:

- Task 4.3.6 is an extension of scope with respect to CARE Annex I,
- The scope of Task 4.4.2 has been modified with respect to CARE Annex I.